SEP 1 1

GAS SPACE HEATING EQUIPMENT MODIFICATIONS

JUNE 1981

A GUIDE TO THE INSPECTION AND INSTALLATION OF VENT DAMPERS AND INTERMITTENT IGNITION DEVICES

PREPARED BY:
THE U.S. DEPARTMENT OF ENERGY
OFFICE OF THE ASSISTANT SECRETARY
FOR CONSERVATION AND RENEWABLE ENERGY
OFFICE OF BUILDINGS AND COMMUNITY SYSTEMS

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

BEST DOCUMENT AVAILABLE

II

GAS SPACE HEATING EQUIPMENT MODIFICATIONS

JUNE 1981

PREPARED BY:

THE U.S. DEPARTMENT OF ENERGY

OFFICE OF THE ASSISTANT SECRETARY
FOR CONSERVATION AND RENEWABLE ENERGY
OFFICE OF BUILDINGS AND COMMUNITY SYSTEMS

WITH

NATIONAL TRAINING AIDS, INC.

ATLANTA, GEORGIA
CONTRACT NO. 86X-61615V

OAKRIDGE NATIONAL LABORATORY

OAK RIDGE, TENNESSEE
OPERATED BY:
UNION CARBIDE CORPORATION
CONTRACT NO. W-7405-ENG-26

PRINT DOCUMENT AVAILABLE

TABLE OF CONTENTS

SECTION 1 GAS SUPPLY FUNDAMENTALS

HISTORY OF FUEL GASES ____ 1
PHYSICAL CHARACTERISTICS OF FUEL GASES ____ 3
FUEL SUPPLY ____ 4
MEASUREMENT OF PRESSURE ____ 5
LEAK TESTING ____ 6
GAS PRESSURE REGULATORS ____ 8
ORIFICES ____ 11
GAS ORIFICE GUIDES ____ 15

SECTION 2 GAS COMBUSTION FUNDAMENTALS

FUEL COMBUSTION CHARACTERISTICS ____ 21
BURNERS ____ 22
PILOT BURNERS ____ 24
MAIN BURNERS ____ 26
MEASURING INPUT RATINGS ____ 32

SECTION 3 HEAT TRANSFER AND VENTING FUNDAMENTALS

CHARACTERISTICS OF HEAT TRANSFER ____ 35
WARM AIR HEATING — HEAT EXCHANGERS ____ 35
HYDRONIC HEATING — HEAT EXCHANGERS ____ 38
VENTILATION ____ 42
VENTING GAS APPLIANCES ____ 43
TROUBLESHOOTING ____ 51
COMBUSTION PRODUCT SAMPLING ____ 53

SECTION 4 BASIC ELECTRICITY REVIEW

BASIC ELECTRICAL THEORY ____ 57
ELECTROMOTIVE FORCE ____ 58
OHM'S LAW ____ 61
ELECTRICAL SUPPLY SOURCES ____ 62

BEST DOCUMENT AVAILABLE

TRANSFORMERS 66
ELECTRICAL SWITCHING 67
ELECTRICAL RESISTIVE LOADS 68
ELECTROMAGNETIC LOADS 68
ELECTRICAL CIRCUITS 70
ELECTRICAL CIRCUIT DIAGRAMS (SCHEMATICS) 72
TEST EQUIPMENT AND CIRCUIT TESTING 73
ELECTRICAL COMPONENT TESTING 77

SECTION 5 BASIC HEATING SYSTEM CONTROL COMPONENTS

PRINCIPLES OF CONTROLS 78
BASIC ELEMENTS OF CONTROLS 78
MANUAL CONTROL COMPONENTS 79
AUTOMATIC CONTROL COMPONENTS 81
TYPICAL APPLIANCE AUTOMATIC CONTROLS COMPONENTS 85
PILOT SAFETY SYSTEMS 88
AUTOMATIC GAS VALVES 89

SECTION 6 GAS SPACE HEATING SYSTEMS

FORCED AIR HEATING SYSTEMS 95
FORCED AIR OPERATING COMPONENTS 97
BOILER STRUCTURE AND OPERATION 102
BOILER OPERATING COMPONENTS 102

SECTION 7 ENERGY CONSERVATION COMPONENTS

ENERGY CONSERVATION 105
PRE-INSPECTION 106
VENT DAMPERS 109
SELECTING VENT DAMPERS 113
INSTALLATION PROCEDURES FOR VENT DAMPERS 118
INTERMITTENT IGNITION DEVICES 121
INSTALLATION PROCEDURE FOR AN IID 125
INSTALLING COMBINATION IID AND VENT DAMPER 127
INSTALLATION PROCEDURE FOR COMBINATION IID AND VENT DAMPER 128

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

SECTION 1

GAS SUPPLY FUNDAMENTALS

HISTORY OF FUEL GASES

Petroleum deposits are generally thought to be the result of decomposed prehistoric plants and animals that created organic sediments over millions of years. Under the heat and pressure created by overlaying sediments and upheavals in the earth's surface, these organic sediments were transformed into petroleum.

Today, this petroleum (as natural gas and crude oil) is found trapped in porous rock formations, in dome-like formations, and in traps created by movements in the earth's crust. Natural gas and crude oil are sometimes found together. However, most natural gas produced in the United States is found in underground pockets that are free of crude oil.

The fuels most commonly used in heating appliances are gases associated with or processed from petroleum. Natural gas (principally methane) occurs naturally and requires only minimal refinement. Liquefied petroleum gases (principally propane and butane) are by-products of the production and refinement of natural gas and other petroleum products. Today, the use of fuel gases for heating applications is approximately 85% natural gas and 15% liquefied petroleum gas.

Uses of Natural Gas

Although widespread use of natural gas is a relatively recent historical event, records and legends of its use date back as far as 2000 B.C. It was used in the temple of Delphi in ancient Greece. Centuries ago the Chinese piped gas from shallow wells through bamboo pipes and burned the gas to evaporate sea water in order to obtain salt. As early as 600 A.D., natural gas wells were tapped for use in Japan, Persia, and Europe. Early explorers of America reported seeing "burning springs" and settlers often struck gas when drilling water wells.

Before natural gas was recognized as a valuable fuel, it was regarded as an annoyance in oil well and mining operations. In the 18th and 19th centuries, natural gas deposits were frequently discovered when mines were constructed. Later, in many oil wells, gas deposits would surface ahead of the crude oil through the casing pipe that was drilled down to the crude oil deposits. Natural gas was called "casing head" gas and was normally burned away at the casing head.

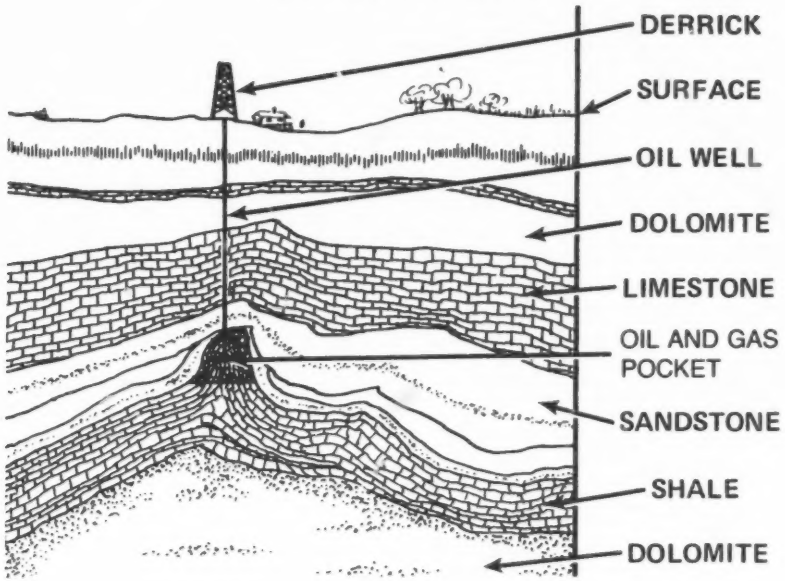
In 1821, a young gunsmith, William A. Hart, intrigued by a "burning spring" near Fredonia, New York, dug a well on a creek bank to tap the gas beneath the surface. By 1824, the gas from this well was used to light the homes, shops, and streets of Fredonia. Deeper wells were drilled in 1858 and the first natural gas company in the United States was formed, the Fredonia Gas Light Company.

Modern natural gas wells are much the same as the early wells in Fredonia, New York (See Fig. 1-1). A long casing pipe extends down through various rock formations to the oil and natural gas deposits. Crude oil frequently must be pumped to the surface. Natural gas, on the other hand, rises through the casing under its own pressure.

Natural gas was initially used in simple burners, primarily for lighting. In 1855, Robert Wilhelm von Bunsen developed the aerated main burner and adjustable orifice. This led to the use of gas for cooking and heating, as well as lighting. Later developments include the gas heater, which was first sold in the U.S. in 1877. In the 1890's, glowing mantles were used to increase light output from gas burners. However, the perfection of the electric light soon led the gas industry to direct its development to other uses. For example, the Electrolux Company in Sweden developed a gas refrigeration system in 1922 and, with Servel, began marketing a gas refrigerator in the U.S. several years later.

FIG. 1-1

NATURAL GAS WELL



Currently, natural gas is used in about 42 million homes in this country. Residential uses include heating, cooking, clothes drying, water heating, refrigeration, air conditioning, and gas lighting. Commercial and institutional users include schools, hospitals, offices, and industries including the electric utilities. Technology has expanded the role of natural gas to include use as a fuel in internal combustion engines, crop drying, and many other unusual commercial and industrial applications. In the last 25 years, advances in the storage and transportation of natural gas in liquid form have opened up potential markets outside the United States, where natural gas is not produced.

Uses of Liquefied Petroleum Gas

Liquefied Petroleum (LP) is a gas which can be stored as a liquid at a moderate pressure and normal temperature. Because of this fact, large quantities of these gases can be stored and transported as liquids in pressurized containers. LP-gas production require more extensive processing and refinement than natural gas. The idea of "bottling" gas goes back to an attempt in London in 1810 to sell compressed gas. In 1870, Pintsch gas was the first liquefied gas produced from oil. Blaugas, developed in 1907, was also produced from oil but very high pressures were required to store it as a liquid. Full development of the "liquid gas" concept required a gas that:

(1) Could be stored and transported at comparatively low pressures.

(2) Maintained a uniform chemical composition.

(3) Was available in comparatively large amounts.

(4) Was reasonably priced.

These requirements were not met until the development of butane-propane gases.

LP-gas was first produced in the refineries of the Riverside Oil Company of West Virginia by the general superintendent, A. N. Kerr, in an attempt to prevent natural gas in storage from vaporizing, or "weathering". This "weathering" was caused by the presence of unidentified components in the gasoline, later found to be propane, butane, and similar gases. Kerr decided to try condensing these vaporized gases. The first experiments produced about 200 gallons of liquefied gas and were reported to the company in 1910.

Kerr and his associates set up a company, American Gasol, to market the LP-gas in 1911. American Gasol made the first installation of LP-gas for residential cooking in Waterford, Pennsylvania, in 1912. Soon thereafter a meat packer in Wheeling, West Virginia produced LP-gas for himself and used it as a fuel in his automobile. The first widespread use of LP-gas was a substitute for acetylene, used in metal cutting. The resulting competition brought a leading producer of acetylene, Carbide and Carbon Chemical Company (which later became Union Carbide) into the LP-gas industry in 1920. Carbide adopted the trade names "Pyrofax" for gas used in cooking applications and "Pyrogene" for gas used in metal cutting applications.

By 1922, the sales of LP-gas were significant enough (223,000 gallons) to warrant the compiling of statistics by the U.S. Bureau of Mines. In the several years that followed, production and marketing capabilities rapidly developed. By 1925, sales had grown to 404,000 gallons; by 1930, they totalled 18 million. In response to this rapid growth, the American Gas Association began certifying appliances for use with LP-gas in 1935.

Although LP-gas found acceptance in many wartime applications, World War II interrupted its growth in civilian applications. With the end of the war the LP-gas industry experienced a period of spectacular growth, establishing it as an important form of energy for homes, agriculture, industry, and recreation. Today, butane is widely used as a raw material in the production of plastics, rubber, gasoline, and a wide variety of other products. Propane, on the other hand, is used primarily as a fuel in gas appliances, internal combustion engines, flame cutting of metals, crop

BEST DOCUMENT AVAILABLE

drying, and frost protection devices. Because of its ease of storage, propane is gaining acceptance as a standby fuel for use when other forms of energy are in short supply.

PHYSICAL CHARACTERISTICS OF FUEL GASES

Natural Gas

Petroleum gases are hydrocarbons - a chemical structure of hydrogen and carbon. Natural gas is primarily methane (CH_4) and ethane (C_2H_6) but it typically contains a number of heavier hydrocarbons when it leaves the well. Among these are propane and butane (the prime constituents of LP-gas), pentane, hexane, septane, octane and decane (the natural gasolines). Natural gas, from the well also contains impurities such as water, carbon dioxide, and helium. The volume of heavier hydrocarbons is called the "wet gas" content. These heavier hydrocarbons are normally removed from natural gas by condensation and are used in the manufacture of LP-gas and gasoline. Impurities are also removed during refinery processes and the resulting "dry" gas is the natural gas commonly marketed.

At temperatures above (minus) − 260 degrees F at atmospheric pressure natural gas occurs as a gas (see Fig. 1-2). It is normally transported from the source to the consumer in a gaseous state by pipeline. Recently, methods have been developed to transport natural gas as a relatively low pressure, low temperature liquid by ocean-going tanker. To accommodate periods of peak demand, natural gas may be stored as a pressurized gas or as a low temperature liquid. Natural gas is costly to liquefy because very low temperatures are required. The use of liquefied natural gas as a motor vehicle fuel is possible only with thick-walled storage tanks, well-insulated to maintain the fuel in a liquid state. As a practical matter, natural gas is only liquefied to make bulk storage and transportation possible.

Natural gas is lighter than air, weighing from 56% to 79% of the weight of an equal volume of air. The specific gravity of natural gas is, therefore, within the range of .56 to .79. Natural gas released into the atmosphere will normally rise and mix readily with air.

When burned efficiently, one cubic foot of processed or "dry" natural gas will normally produce between 900 to 1,200 British Thermal Units (Btu's) of heat. This is called the gross heating value of natural gas and is an important factor in the design and operation of heat-producing appliances.

Natural gas is colorless, odorless, and nontoxic. Although nontoxic, it can displace oxygen in the air and cause unconsciousness and death through asphyxiation (death due to lack of oxygen). To aid in the detection of leaks, odorants are normally added to natural gas before distribution. *Mercaptans* are sulfur compounds commonly used as odorants. Although added in small amounts, they provide an effective means of detecting gas leaks.

LP-Gases

Propane (C_3H_8) and butane (C_4H_{10}) are chemical compounds of hydrogen and carbon (hydrocarbons) which occur in "wet" natural gas and in crude oil. These heavier gases are removed from "wet" natural gas along with other impurities in order to produce "dry" natural gas for distribution. In oil refineries these gases are produced in the process of manufacturing gasoline and other petroleum products. In 1971, approximately 74% of all LP-gas marketed was produced at the well from "wet" gas; the remaining production came from refineries. The ratio of production from wells and refineries varies from time to time, but in general, the newer gasoline-making processes are yielding a higher percentage of propane. At normal temperatures and atmospheric pressure, both butane and propane occur in a gaseous state. Pure butane will condense to form a liquid at temperatures below 32 degrees F when it is at atmospheric pressure. Pure propane will condense to form a liquid at temperatures below (minus) −44 degrees F when it is at atmospheric pressure (see Fig. 1-2). Both gases, however, will condense to form a liquid at normal temperatures and relatively low pressures.

Processed butane is normally 93% butane and 7% propane; processed propane is normally pure. LP-gas is distributed as a liquid by pipelines, rail cars, tanker trucks, and tanker ships and barges. It is normally stored in pressurized tanks. Transportation to the consumer is usually by bulk truck. Storage at the point of use is in small tanks or cylinders, as a liquid under pressure.

Both butane and propane gases are heavier than air with specific gravities of 2.00 and 1.53 respectively. Neither propane nor butane gas will rise and disperse as quickly as natural gas when released into a nonventilated area. Because both gases are heavier than air, LP-gas will normally settle in calm air to form pockets, or hover around the source of the leak. With turbulence of ventilation, LP-gas dissipates almost as quickly as natural gas.

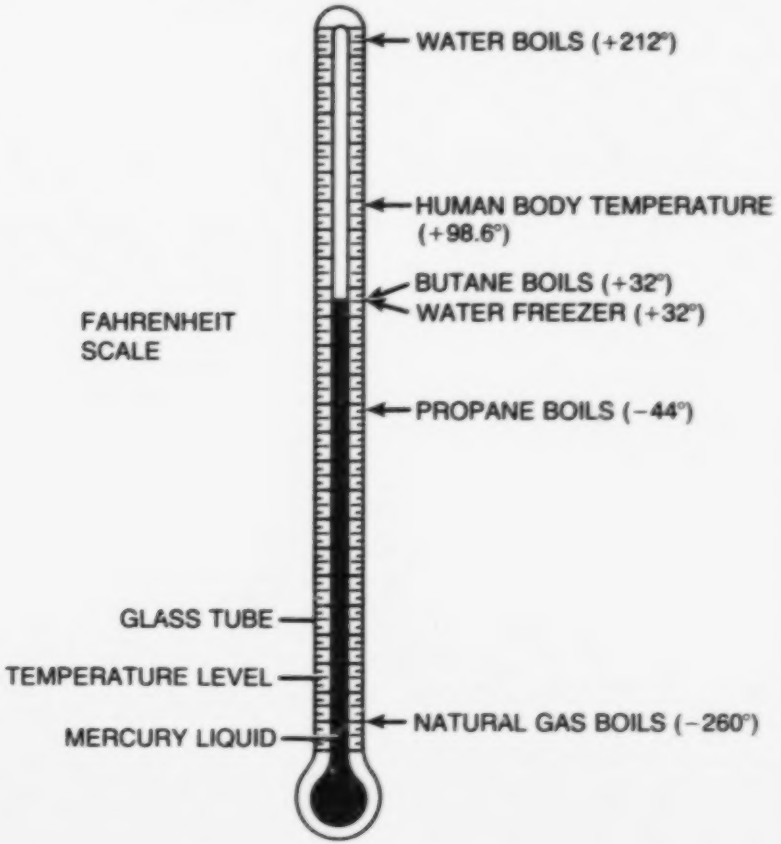
Propane has a gross heating *value* of about 2500 Btu/cubic foot; butane has a gross heating *value* of about 3225 Btu/cubic foot. A given volume of LP-gas, therefore, will produce 2½ to 3 times the number of Btu's as an equal volume of natural gas. This is an important consideration in the conversion of appliances from one fuel gas to another.

Butane and propane are colorless, odorless, and nontoxic. LP-gases also can displace oxygen in the air and cause unconsciousness and death through asphyxiation. To aid in the detection of leaks, odorants are normally added to LP-gas before distribution to the consumer. In nonventilated areas, LP-gas leaks are more difficult to detect than natural

BEST DOCUMENT AVAILABLE

FIG. 1-2

MERCURY THERMOMETER



gas leaks because LP-gas does not rise and disperse in air as readily as natural gas.

In summary, Petroleum gases utilized in heating appliances are natural gas and liquefied petroleum gas. Natural gas occurs as a gas naturally and requires minimal refinement. LP-gas occurs in "wet" natural gas and crude oil and must be extracted and refined before use. Natural gas is normally distributed in pipelines as a gas; LP-gas is usually transported under pressure as a liquid. Both gases are colorless, odorless, and nontoxic in their natural states. Natural gas is lighter than air and will rise and disperse. LP-gas is heavier than air and will settle and hover around the source of a leak.

FUEL SUPPLY

Gas Pressure

In order to truly understand fuel supply, it is important first to discuss gas pressure. Basically, gas pressure is the force exerted by a gas on the walls of a container or pipe. This pressure is normally written as force per unit of surface area. If the force is measured in pounds and the area is measured in square inches, then the pressure is written as pounds per square inch (psig).

Pressure is usually measured under two conditions: when the gas is stationary and when the gas is moving. When gas in a pipe is stationary, or not moving, the pressure on the walls of the pipe is considered "static". An example of static pressure would be an automobile tire filled with air. When a tire is filled with air, the air expands equally in all directions.

As a result, a measurement of the static pressure *anywhere* in the tire will indicate the static pressure *everywhere* in the tire.

Regardless of the type of gas (air, natural gas, etc.), the static pressure of the gas will be the same everywhere in a closed system.

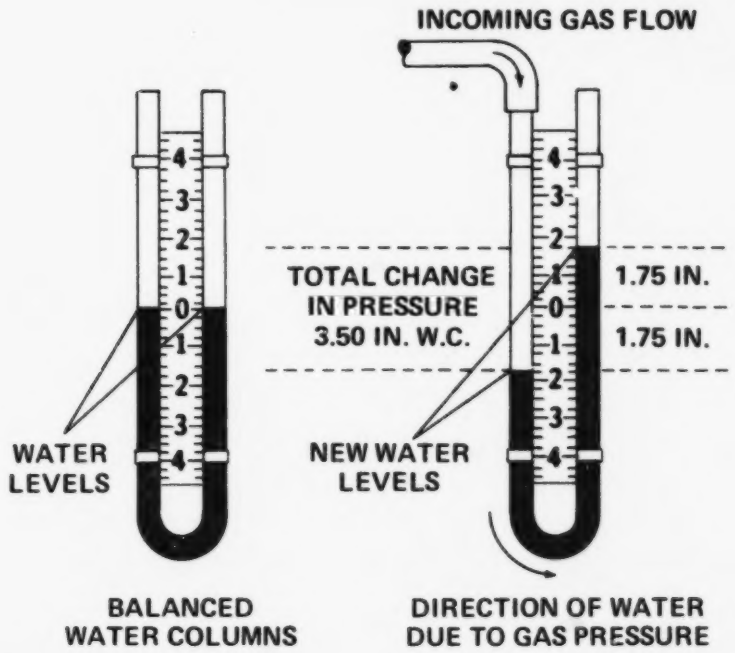
When gas is moving through a pipe, there are several factors that affect the pressure of the gas. First, in order to force gas to move from one point to another, there must be a difference in pressure. In a home, for example, the gas inside the piping will not flow to the appliance until the gas cock is opened. When the gas cock is opened, the gas is allowed to flow to a burner, that is open to the atmosphere. Gas will flow as long as the pressure in the piping is *higher* than the pressure of the atmosphere outside the burner. If the supply of gas to the piping decreases, the flow of gas through the pipe will decrease. In the design of gas distribution systems, it is important to ensure that a consistent supply pressure be maintained throughout the piping system.

Another important factor affecting gas flow through a system is the loss of pressure due to *friction*. In a piping system, the supply or inlet pressure is normally the highest pressure in the system. If the pressure is measured downstream from the inlet, it will be slightly less than the inlet pressure. The difference between the two readings is due to the friction of the gas moving against the pipe wall, fittings, or valves in the piping, or any other obstacles to the flow of gas. This friction creates a drag in the gas flow and reduces the volume of gas that can flow through the piping system. As a result, the gas pressure at any point downstream from the supply is lower than the inlet pressure as long as gas is moving through the piping. When designing gas piping systems, the pressure loss caused by friction should *always* be minimized.

BEST DOCUMENT AVAILABLE

FIG. 1-3

MANOMETER



Measurement of Pressure

There are two ways of expressing pressure: *gauge* and *absolute*. *Gauge* pressure is the most common. It is used to describe gas or liquid pressure in an enclosed system, such as a gas storage container or a gas piping system. Basically, it is the gas or liquid pressure in the system excluding the pressure of the atmosphere outside. A *positive* gauge pressure in a gas piping system indicates that the pressure in the pipe is higher than the atmospheric pressure. Gauge pressure is normally expressed with the word "gauge" or the letter "g" after the reading (for example, psig).

Absolute pressure is always the gauge pressure *added* to the pressure of the atmosphere (14.7 psi at sea level). If the gauge pressure of a gas was 10 psig. in a storage container at sea level, the absolute pressure would be 24.7 psia (10 + 14.7). Absolute pressure is normally expressed with the word "absolute" or the letter "a" after the reading (for example, psia).

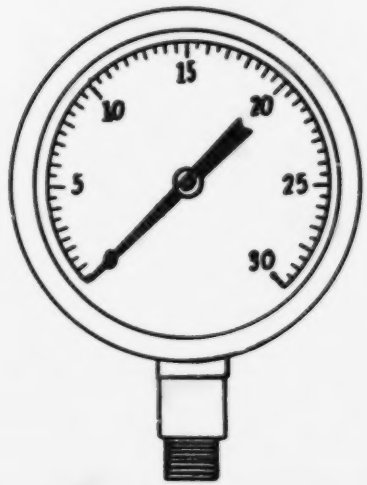
The two devices commonly used to measure the relatively low pressures (less than 1 psig) used in gas appliances are the manometer and the low pressure test gauge. The manometer (see Fig. 1-3) is a transparent U-shaped tube with a scale marked in inches on each leg of the U. The tube is filled with water until the water level in each leg is at the zero mark. One end of a flexible hose is connected to one side of the U-tube. The other end of the hose is connected to the point where the pressure is to be measured.

As gas enters the flexible hose, pressure is applied to one column of water. Atmospheric pressure is exerted on the other column of water. In order for the column of water to move, the gas pressure must overcome the pressure of the atmosphere (positive gauge pressure) on the "open" side of the manometer. Once the gas pressure exceeds the atmospheric pressure, the column of water moves and the reading shown is the gauge pressure of the gas flowing into the manometer. The reading can be determined by *adding* the distance from the zero mark that *each* column of water has moved. In Figure 1-3, one column of water moved down 1.75 inches and the other column of water moved up 1.75 inches; thus, the gauge pressure is 3.50 inches of water column. Pressure measured in this manner is expressed in "inches of water column" (in. W.C.). As a reference, 27.7 in. W.C. is equal to 1 psig or 16 ounces per in.^{2} gauge.

The low pressure test gauge (see Fig. 1-4) is normally a diaphragm-type spring gauge. The gauge consists of two relatively flat metal diaphragms joined at their edges with a space between. The pressure to be measured is

FIG. 1-4

LOW PRESSURE TEST GAUGE



BEST DOCUMENT AVAILABLE

FIG. 1-5

BOURDON TUBE TEST GAUGE

FILL – Complete fill when specified eliminates air bubble for better read ability
DIAL – White background with jet black embossed figures and gradu ations
POINTER – Micr- adjustable
RING – Threaded – Black fiberglass reinforced polypro pylene
WINDOW – Acrylic plastic – has out standing weatherability "O" ring seal available for weather proof service
SEAL – Positive "O" ring seal 3 with sponge rubber dust seal. Positive "O" ring seal available for weather proof service
SOCKET – Available in brass, alloy steel or 316 Stainless Steel
CASE – Black – fiberglass reinforced polypropylene.
BLOW OUT BACK
DIAPHRAGM SEAL – for tempera ture compensation. Diaphragm is not furnished on dry gauge
BOURDON TUBE – Phosphor bronze or Type 316 Stainless Steel Type 403 Stainless Steel is furnished above 10,000 psi
MOVEMENTS – Brass with bronze bushings, Stainless Steel with Stainless Steel bushings, Stainless Steel with Delrin bushings and delrin sector gear.
MOUNTING PLATE – Heavy mount ing plate withstands installation torque.
CASE FRONT – Solid – prevents window blow-out, improves safety

applied between the diaphragms while atmospheric pressure is naturally applied to the outside. The gas pressure causes the diaphragm to bulge. This movement is indicated by a pointer which moves along a round scale to show the measured pressure. The gauge scale is normally designed to read in "ounces per square inch," "inches of water column," or both.

When higher pressures (above 1 psig) are to be measured, the devices commonly used are the bourdon tube-type test gauge or the mercury manometer. The mercury manometer is similar in design and operation to the water manometer. Because mercury is much heavier than water, a greater pressure is required to push the column of mercury in the U-tube. Since Hg is the chemical symbol for mercury, pressures measured by a mercury manometer are expressed in "inches of mercury column" or "in. Hg." As a reference, 2.0 in Hg is approximately equal to 1 psig.

The bourdon tube test gauge consists of a curve-shaped metal tube. This device is shown in Figure 1-5. One end of the tube is open while the other end is sealed. A flexible hose is used to connect the open end of the tube to the gas source. As the pressure of the gas from the source is exerted on the inside of the tube, the tube tends to straighten. This movement is transferred to a pointer which moves along a round scale to indicate the measured pressure. The gauge scale may be designed to read in "pounds per square inch (psig)," "in. Hg," or both.

LEAK TESTING

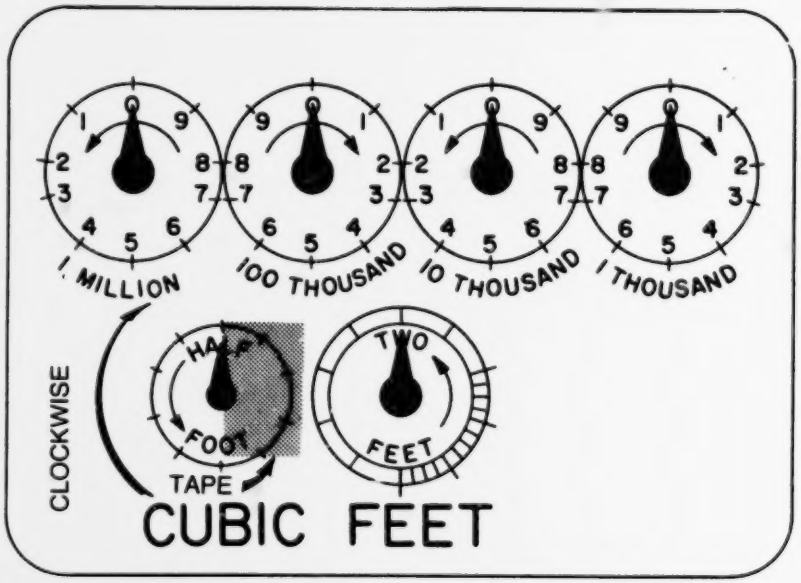
The National Fuel Gas Code (ANSI Z223.1, NFPA #54) requires that a leak test be performed immediately after gas has been established to a fuel gas piping system and connected to gas-consuming appliances. The code states that one of two methods can be used to perform a leak test. One method is to use a gas meter and carefully watch the test dial for any movement. The second method is to use a pressure sensing device, such as a manometer or low pressure gauge, to test for leakage.

Leak Testing Using a Gas Meter (Clocking)

According to procedure detailed in Z223.1, NFPA #54, a meter must be in operational condition (and has not been "jumped out" or by-passed) before it can be used to leak test a fuel gas piping system. The objective in the meter-type of leak test is to close all normal outlets (main and pilot burners), and observe the meter's low volume test dial for gas flow. If gas flow is indicated on the meter dial, gas is escaping from the gas fuel system

FIG. 1-6

TYPICAL DOMESTIC GAS METER INDEX



BEST DOCUMENT AVAILABLE

piping and/or an appliance(s) connected to the system. The procedures for this type of test are as follows:

1. Check to ensure that the meter is in operational condition and has not been by-passed. To ensure that the meter is operational, purge the meter outlet. This can be accomplished by slightly loosening the swivel connection to the outlet of the meter. *Caution:* Allow *Only* a small volume of gas to escape and be certain there are *no* ignition sources in the area. While purging, if the meter shows no movement, replace it or notify the gas supplier or utility.

2. Close all sources of gas to both pilot and main burners on each appliance. This includes turning the main gas valve control to the off position and closing all gas pilot adjustment screws. Ensure that gas shutoff valves are in the closed position on fuel gas lines where appliances have not been connected. Also ensure that the ends of the lines are plugged or capped.

3. Observe the test dial face. Select the dial with the lowest flow rate (1/4 or 1/2 cubic foot test dial). Place a small piece of tape over the test dial face parallel to the edge of the dial indicator (see Fig. 1-6). This procedure provides you with a reference to monitor movement of the test dial indicator. Ensure that it is on the upsweep for this observation or moving up toward the 12 o'clock position.

4. Time and observe the dial for gas flow (a leak). Various styles of meters have test dials which indicate different flow rates. A chart below indicates the length of time the test dial should be observed for each of the common test dials.

DIAL STYLE	TEST TIME
1/4 cu. ft. dial	5 minutes
1/2 cu. ft. dial	5 minutes
1 cu. ft. dial	7 minutes
2 cu. ft. dial	10 minutes
5 cu. ft. dial	20 minutes
10 cu. ft. dial	30 minutes

5A. If, after the indicated test time there is *no* movement of the test dial indicator (*no flow of gas*), the gas may be left on.

B. If, however, after the indicated test time there *is* a movement in the test dial indicator (*a flow is indicated*), a leak is present and must be isolated and corrected. A soap-water or other bubble-forming leak detector solution can be applied to the suspected leaking fuel gas piping, fittings or components. A combustible gas leak indicator may be used to locate the leak. In any vent, isolate and correct the leak *before* turning the gas on or placing the appliance(s) in operation.

6. To ensure that the meter is operating properly after the test has been performed, purge the piping system. ANSI Z223.1, NFPA #54 details purging procedures such as disconnecting the pilot piping at the outlet of the pilot valve and purging the air from the piping. It should be noted that piping *shall not* be purged into the combustion chamber of an appliance. It should also be noted that purging shall not discharge into confined spaces or areas where there are ignition sources. All purging must be performed in a safe manner. The space must be ventilated. The purge rate must be controlled and all hazardous conditions eliminated.

7. After the system has been purged, ensure that the meter is operating properly by igniting one small burner within the system and observing the low volume test dial. If the meter test dial does not indicate gas flow, the meter must be replaced with an operational meter *before* the gas supply can be established to the fuel gas piping system. Notify the gas supplier or utility.

Leak Testing with a Low Pressure Test Device

Another test method detailed in ANSI Z223.1 requires that the fuel gas piping system within a home or building hold a static pressure equal to the normal working low pressure (3-7" W.C. natural gas; 10-14" W.C. LP-gas) of the gas systems for a period of not less than *3 minutes* without *any* drop in the gas pressure. Either a manometer or pressure gauge may be used for this type of leak test. The objective in this type of leak test is to pressurize the fuel gas piping system within the building with normal working gas pressure. Seal the supply by closing the inlet gas supply gas valve and monitor the sealed pressurized piping for a drop in pressure. Obviously, any drop in pressure indicates a leak. The procedure for this type of test is as follows:

1. Close all sources of gas to both pilot and main burners. This includes turning the main gas valve control on the appliance(s) to the "off" position and closing all pilot gas adjustment screws.

2. Connect the hose from the manometer or low pressure test device to an available gas valve outlet or orifice (the top burner orifice on a range is an ideal location). If a range is not available, the test device can be connected to the system by means of a "T" fitting (see Fig. 1-7). As the figure illustrates, the "T" can be inserted between the appliance connector and the gas valve to the appliance. (Ensure that the "T" fitting is tightened securely so a leak is not created).

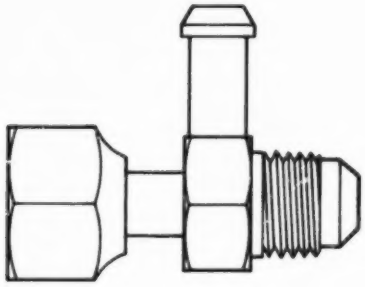
3. After the test device is in place, open the main gas valve or service valve at the meter or storage tank. Also, open the main gas valve from the supply line to the appliance. As soon as the supply is turned

BEST DOCUMENT AVAILABLE

on, the test device should indicate a positive pressure *at least* as high as the normal working pressure of the appliance (3-7" W.C. natural gas; 10-14" W.C. LP-gas).

FIG. 1-7

"T" FITTING



4. Immediately after the main gas valve or service valve has been turned on, return it to the "off" position. This action pressurizes the piping.

5. Return to the test device location. Slightly loosen the test device hose from its connection and allow enough gas to escape to decrease the test device reading 1/2" W.C. or 1/3 oz. This basically reduces the pressure within the system to slightly below the regulator setpoint. Firmly reattach the hose and monitor the test device for no less than *3* minutes.

6. If the reading on the test device gradually decreases, a leak is present. Locate and correct the source of the leak. If the reading gradually increases, the main gas valve or service valve is bleeding gas into the fuel gas piping being leak tested. This malfunction must be corrected since it can be as dangerous as a leak in the piping system.

7A. If after *3* minutes of testing, the test device reading shows no drop in pressure, turn off the appliance gas supply, then disconnect the test device hose from the range burner orifice or remove the "T" fitting, and securely reconnect the appliance connector.

B. If, after *3* minutes of testing, the test device *shows a drop* in pressure, the leak must be isolated and corrected. A soap-water or other bubble-forming solution can be applied to suspected leakage areas or a combustible leak gas indicator may be used to locate the leak. In any event, locate and correct it before turning the gas on or placing the appliance(s) in operation.

C. Retest before turning on gas to make certain that *all* leaks have been found.

GAS PRESSURE REGULATORS

In order for a gas appliance to operate efficiently and safely, the pressure of the gas delivered to it must be constant, despite changes in supply pressure or the demand for gas. Pressure regulation results in both a uniform gas flow rate and dependable, predictable burner operation.

In order to obtain constant pressure, gas pressure regulators are designed to reduce the gas supply pressure by restricting gas flow through the regulator. When upstream pressures are higher, the regulator automatically closes to further restrict the flow and maintain a uniform, stable downstream pressure. Because it operates by restricting the flow of gas, a pressure regulator can only reduce higher inlet pressures to the desired outlet pressure. If the inlet pressure is less than the desired outlet pressure, the regulator provides no regulation function.

Categories of Regulators

Natural gas pipelines transporting gas over long distances operate at high pressures to maximize the quantity of gas which can be moved. "Distribution Regulators" are used to reduce and regulate these higher pipeline pressure to pressures suitable for street mains. "Service Regulators," normally located where gas lines enter buildings, further reduce and regulate the pressure from the street main. Service regulators for natural gas are frequently located adjacent to gas meters.

LP-gas service regulators are usually located at the storage tanks. LP-gas service regulation can be accomplished in one or two stages. In single stage regulation, one regulator reduces tank pressure (100-250 psig) down to appliance pressure (11-15" W.C.). Two stage regulation uses two independent service regulators. The first reduces gas pressure to 11-15 psig; the second reduces the pressure down to appliance pressure of 11" W.C. Because service regulators are the responsibility of the gas supplier or utility, the major emphasis will be on appliance regulators.

"Appliance Regulators," which provide a final stage of pressure reduction, are a vital part of the appliance control system. Appliance regulators are certified by A.G.A. as Class I or Class II based on maximum allowable inlet pressure. Essentially, Class I regulators are intended for use on natural gas, and Class II are for LP-gas. Class I regulators must function at inlet pressures from 4 1/2 to 10 1/2 in. W.C.; Class II regulators operate at inlet pressures from 10 to 21 in. W.C. Today, many appliance regulators are available for use with either natural or LP-gas. These regulators are

BEST DOCUMENT AVAILABLE

common on modern cooking ranges. Maximum capacity of dual-approved models is typically lower than comparable single-approved models. In addition these regulators normally do not respond as accurately to changes in load and inlet pressure. Appliance regulators are also classified as *adjustable, convertible,* or *fixed. Adjustable* regulators allow field adjustment of outlet pressure. *Convertible* regulators can be quickly and conveniently converted from natural gas operation to LP-gas or vice versa. *Fixed* or nonadjustable regulators cannot be adjusted in any way.

Structure of Regulators

There are two types of pressure regulators in common use: lever-type and stem-type. Stem-type regulators are separated into two chambers bv a flexible barrier called a diaphragm (See Fig. 1-8). A cone-shaped hole or valve seat is located in the lower chamber. A matching cone-shaped valve in the lower chamber is attached to a shaft which extends up through the orifice into the upper chamber. The shaft is attached to the center of the flexible diaphragm. The area above the diaphragm is vented to the atmosphere. The area below the diaphragm is open to the gas supply. As a result, the lower chamber houses both the gas inlet and outlet. A coil spring pushes down on the diaphragm. An adjusting screw is located on top of the spring in the top of the regulator and allows adjustment of spring tension. In operation, the diaphragm moves in response to changes in outlet pressure caused by changes in either demand or inlet pressure, or both. When demand increases, outlet pressure drops slightly. The diaphragm moves in response to this change, opening the regulating valve to allow the outlet pressure to increase slightly.

When inlet pressure rises, the diaphragm responds by closing the regulating valve to maintain outlet pressure.

Lever-type regulators have a spring and diaphragm arrangement similar to the stem type regulators. (See Fig. 1-9). The shaft from the diaphragm actuates a relatively long lever arm linkage. The lever moves the shutoff disc against an orifice, opening and closing the valve in response to the diaphragm position. The lever linkage provides a mechanical advantage, allowing the regulator to assure positive shutoff of higher inlet pressures.

The vent in the upper chamber of most pressure regulator is designed to allow air to move in and out of the chamber as the diaphragm moves. If the diaphragm ruptures, gas will escape through the vent. In modern appliance regulators, the vent is normally fitted with a leak limiting orifice; if not it must be vented to the outside or to a pilot burner by means of tubing.

FIG. 1-8
APPLIANCE REGULATOR

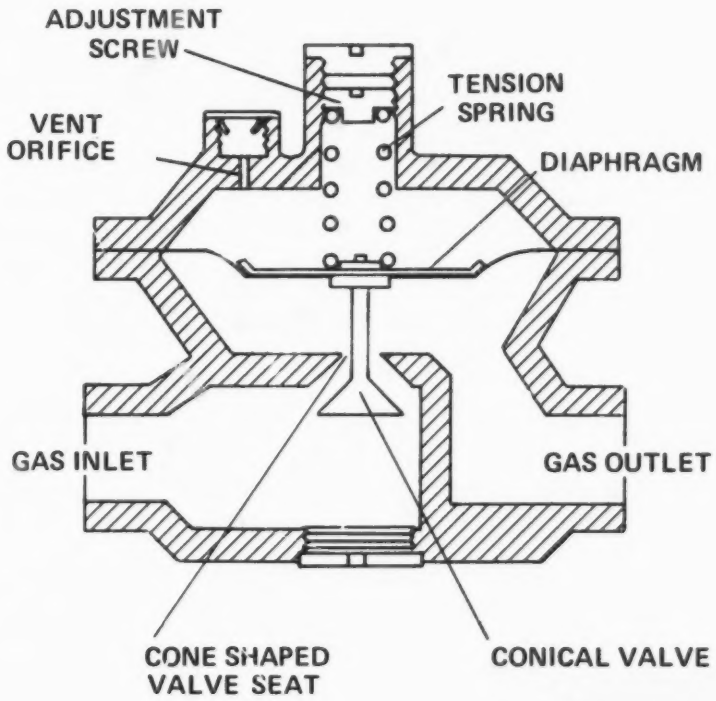
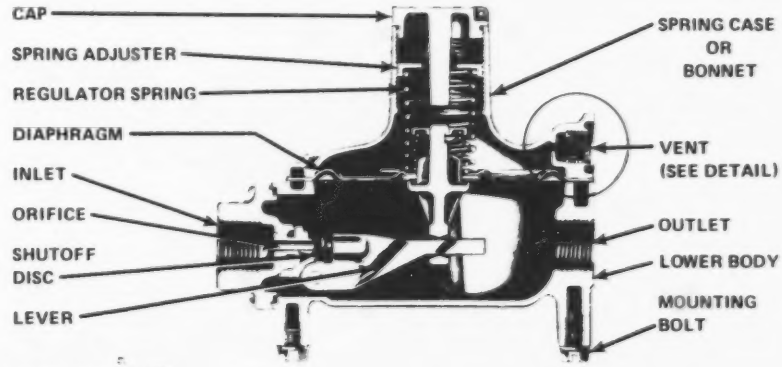


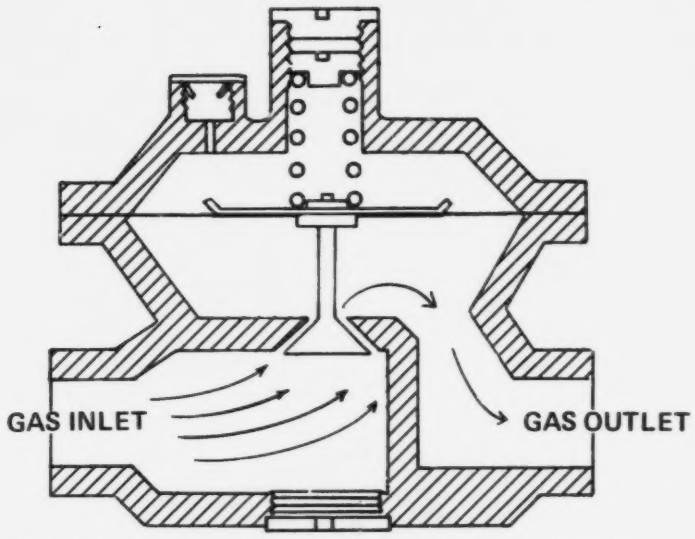
FIG. 1-9
LEVER TYPE REGULATOR



BEST DOCUMENT AVAILABLE

FIG. 1-10

HIGHER INLET PRESSURE



VALVE CLOSES TO ALLOW LESS GAS TO FLOW

Operation of Regulators

According to ANSI standards, each class of regulator has a range of inlet pressures over which a regulator should operate. To meet ANSI standards, the regulator outlet pressure must not vary more than 20% over the specified range of inlet pressures. The difference between the maximum gas flow rate and the minimum gas flow rate at which a regulator will meet ANSI standards is called the *range of regulation*. The appliance regulator must operate effectively at *pilot load* when only 0.1 to 1.0 cubic foot per hour (cfh) of gas is being burned and also at *full load* when the main burner is operating. A stem type regulator is shown at pilot load in Figure 1-10 and full load in Figure 1-11. An abrupt increase in gas flow rate such as the increase from pilot load to full load can cause a temporary sharp drop in outlet pressure. This drop is called regulator *"droop"*. Better regulators are designed to minimize "droop".

As the inlet pressure increases, or as the demand for gas decreases, the pressure regulator valve will partially close to maintain a constant outlet pressure. In some cases, when the demand is cut off or if the inlet pressure becomes too high, the valve is forced against the seat, completely cutting off gas flow through the regulator. This condition is called "lock-up" and the inlet pressure at which it occurs is called "lock-up" pressure. Figure 1-12 shows a stem-type regulator in the lock-up condition. When the high inlet pressure is reduced to the normal range, the regulator will function normally. Pressure readings during lock-up conditions should be only slightly higher than readings during normal operations. Excessive lock-up pressures indicate a dirty or worn valve and seat assembly.

Adjustment of Appliance Regulators

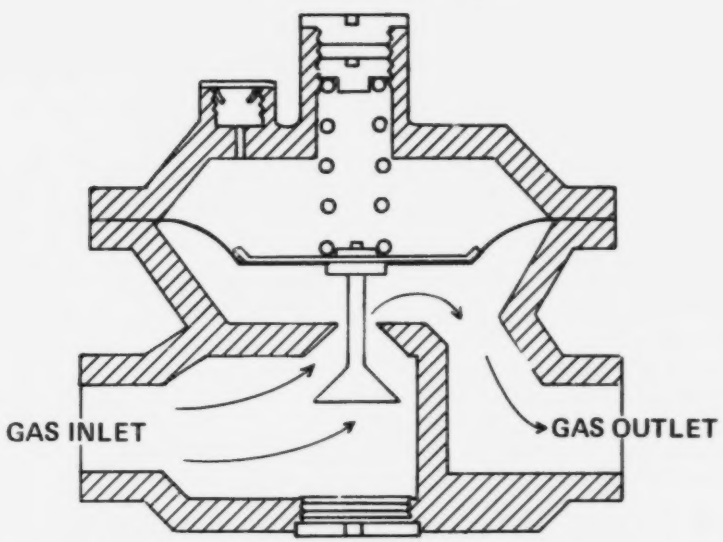
If regulator adjustment is necessary, a pressure measuring device such as a manometer or low pressure test gauge is required.

1. Turn the gas supply off upstream from the regulator.

2. Locate the "pressure tap" fitting on the downstream side of the appliance pressure regulator. Remove the "pressure tap" plug; install a suitable adaptor, and connect the pressure test device. In heating appliances the pressure tap is normally located on the main burner manifold or on the outlet of the main gas valve itself. If a "pressure tap" fitting is not available, connect the pressure test device to the nearest suitable outlet or to a "T" fitting.

FIG. 1-11

LOWER INLET PRESSURE

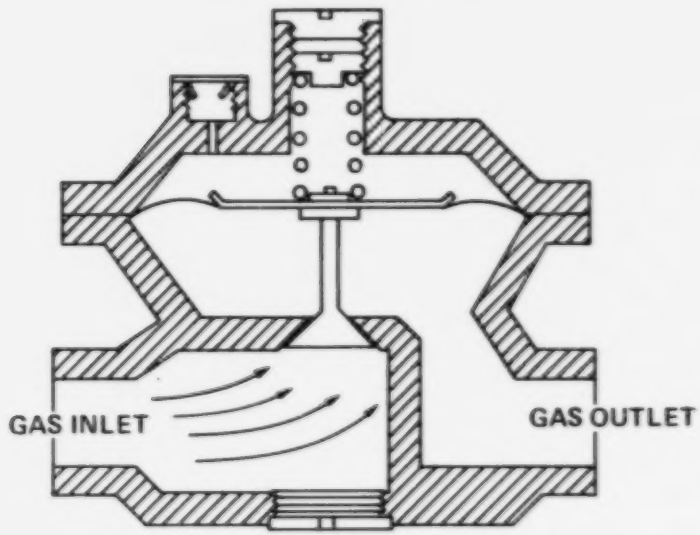


VALVE OPENS TO ALLOW MORE GAS TO FLOW

BEST DOCUMENT AVAILABLE

3. Turn the gas supply on and operate the appliance at pilot load and full load. Under both conditions, appliance regulators should maintain near constant pressure. The normal adjustment range of a natural gas appliance regulator is 2-5 in. W.C.; on an LP regulator it is 9-13 in. W.C. If regulator adjustment is necessary, turn the adjusting screw to increase or decrease tension on the regulator spring. Adjustments should be made only at 50% or more load; in heating appliances the main burner should be operating. After adjusting, recheck the outlet pressure at pilot load and full load.

FIG. 1-12
LOCK-UP CONDITION



Malfunctions

Appliance regulator failure can result in a number of problems. If regulator failure is suspected, connect a pressure measuring device and observe outlet pressure while operating the appliance pilot and main burners. Compare regulator symptoms to these common malfunctions.

SYMPTOM	CAUSE	CORRECTIVE ACTION
1. Outlet pressure too high under all flow conditions; gas escaping through regulator vent.	1. Ruptured diaphragm.	1. Replace regulator.
2. Outlet pressure too high *or* too low and adjustment ineffective; erratic pressure.	1. Broken or worn valve.	1. Replace regulator.
	2. Restricted vent.	2. Clean vent or replace regulator.
3 Outlet pressure too high during low flow operation or lock-up condition.	1. Dirt around valve seat.	1. Clean valve, replace or repair regulator.
	2. Restricted vent.	2. Clean vent or replace regulator.
4. Outlet pressure unstable; pressure drops during high flow operation.	1. Restricted or (plugged) vent.	1. Clean vent or replace regulator.

ORIFICES

An orifice is a precisely sized hole used to control the amount and direction of gas that flows through a system. By supplying gas at a regulated pressure to an orifice of known size, a specific, predictable, and constant flow of gas or "input" can be achieved.

Most orifice designs allow for converting appliances from natural gas to LP-gas and adjustment of appliance operation for changes in altitude.

Pilot Burner Orifices

Pilot burner orifices are normally brass or aluminum. They are manufactured in two types: the insert-type and the threaded-type. The insert-type (See Fig. 1-13) simply slides into a receptacle and is held in place by a pilot tube inlet fitting. The orifice opening in an insert-type is either rectagular, circular or in the shape of the letter "D". The Spud type (See Figure 1-14) has a threaded seat which is screwed into the pilot burner assembly. The orifice opening in a threaded orifice is usually circular.

Main Burner Orifices

Main burner orifices are normally brass, iron, or aluminum. They are frequently either the "plug-type" or the "cap-type". The "plug-type" (See Fig. 1-15) is a male threaded plug with an orifice in the head of the plug. The plug type screws into the gas supply manifold. The "cap-type" (See Fig. 1-16) is normally a 1/8 inch NPT female threaded "cap". The "cap-type" orifice is screwed onto the supply manifold or valve. Most main burner orifices in heating appliances are the "plug-type".

Orifices are very simple devices and proper operation under normal conditions depends solely on proper selection and installation. Proper

BEST DOCUMENT AVAILABLE

FIG. 1-13

INSERT TYPE PILOT ORIFICES

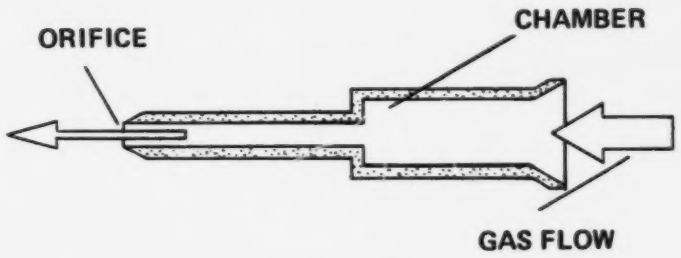


FIG. 1-14

SPUD TYPE PILOT ORIFICE

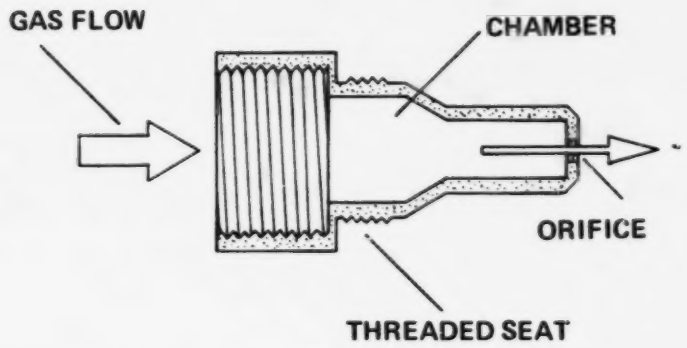


FIG. 1-15

PLUG TYPE ORIFICE

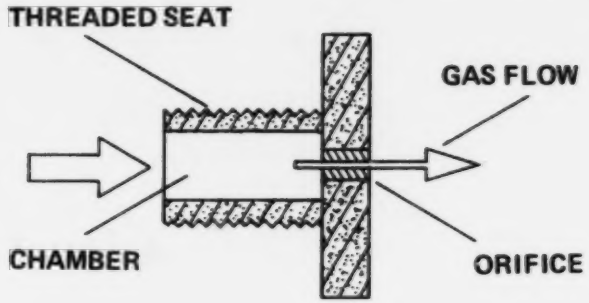
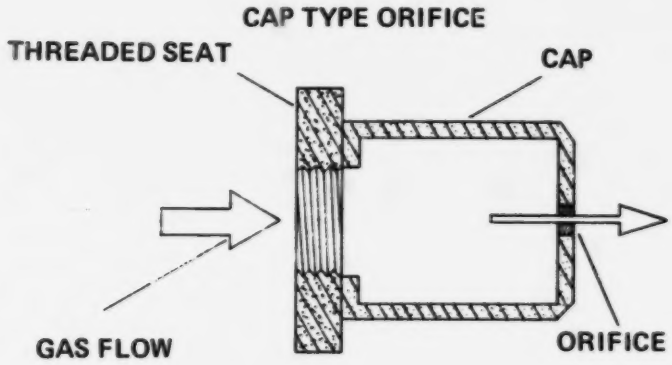


FIG. 1-16

CAP TYPE ORIFICE



selection includes choosing the correct orifice type and size. Orifice size is rarely changed, except to convert the appliance to another type fuel gas (LP-gas, natural gas).

Factors Affecting Main Burner Orifices

The type fuel gas, the consumption rate, and the gas supply pressure determines the size and configuration of the main burner orifice.

Propane and butane gases are heavier than natural gas. A molecule of propane or butane weighs more than a molecule of natural gas. The gross caloric value of LP-gas is higher than that of natural gas. For example, when one cubic foot of propane is burned efficiently, it gives off 2500 Btu's of heat, while one cubic foot of natural gas will yield only 900-1200 Btu's.

There are heat losses in all applications due to a variety of factors. Therefore, when discussing input or consumption rate of gas appliances, remember that 100% efficiency is used as a reference. In practical applications, this value is impossible to achieve.

Since the gross heating value of LP-gas is higher than natural gas, it takes less LP-gas than natural gas to produce the same amount of heat. The orifice size regulates the amount of gas discharged to a burner. If a heating system is to be converted from natural to LP-gas, the LP-gas orifice should be smaller than the orifice used with natural gas. Therefore, type of fuel gas is the first factor affecting the size of any orifice.

Gas consumption rate or input is the second factor which determines orifice size. The consumption rate or input is the amount of gas used by an

BEST DOCUMENT AVAILABLE

appliance during a certain period of time. This amount is normally expressed by the cubic feet of gas used per hour of operation.

If a specific gas appliance completely burns 50 cubic feet of natural gas every hour, then approximately 50,000 Btu's (50 Cu. Ft/hr. × 1000 Btu/cu. Ft.) of heat is given off. It can be seen that the amount of heat given off or the volume of gas required by an appliance will also affect orifice size.

It is important to understand, that *all* appliance orifices equally contribute to the amount of heat given off by the appliance. To determine the exact input of *each* orifice the number of orifices (number of main burners) must be divided into the total input. For example, if an appliance with 5 main burners has a total input of 50,000 BTU's each burner orifice is rated at 10,000 BTU's (50,000 BTU's ÷ 5).

A third factor affecting orifice size is the gas pressure of the gas flowing into it. This pressure is called the manifold pressure. Manifold pressure is normally measured by a manometer and expressed in inches of water column. In the previous example, the orifice allowed 50 cubic feet of natural gas to flow to the burner every hour. The pressure of the gas going into the orifice is 3" water column. If the manifold pressure is increased to 3 1/2" water column, the same orifice size will allow 55 cubic feet of natural gas to flow to the burner. This means approximately 5 additional cubic feet of natural gas will be burned every hour . The additional natural gas will give off approximately 5,000 additional Btu's (5 cu. ft./hr. × 1,000 Btu/cu. ft.). Therefore, the manifold pressure must be determined before the orifice size changes are made. The manifold pressure affects both the total gas volume that will flow through an orifice, and in turn, the total heat given off.

Orifice Sizing

Each of the three factors affect the orifice chosen for a specific gas appliance. Since there are many sizes that can be used, values were tabulated for various pressures and compiled into orifice guides. Note that the heating values in Figure 1-17 through 1-19 are the "input rating". The "output rating" of the appliance will be a lesser value than rated input because efficiencies are less than 100%. Figure 1-17 is an orifice guide for natural gas. Figure 1-18 is an orifice guide for butane and Figure 1-19 is an orifice guide for propane.

Use Figure 1-17 as an example, column 1 ("Drill No.") lists all the orifice sizes by corresponding drill size numbers. This is an arbitrary number given to drills having a specific diameter. Figure 1-20 lists the diameter for each drill number. For example, the designation #3 is the same as a drill diameter of .213 inches. Therefore, a drill number on an orifice of #3 would indicate an orifice size of .213". This type of designation makes orifice sizing an easy process. If an orifice must be enlarged, a corresponding drill (i.e., #4, #3, #2, etc.) may be used and the old orifice enlarged by drilling.

When using an orifice guide, first determine the type of gas being used by the appliance. With the burner operating, the manifold pressure must then be determined in inches water column, using a manometer. Once the gas pressure is determined, a specific orifice size can be chosen with corresponding gas flow data. For example, in Figure 1-17, the column headed 3" W.C. contains all gas glow data for any of the orifice sizes listed. Further, by choosing an orifice size of #1, the orifice will allow 136 cubic feet of natural gas to flow through to the burner in one hour at 3" water column manifold pressure. This quantity of natural gas will give off approximately 136,000 Btu's of heat when burned at 100% efficiency.

To match a specific orifice size with a desired heat input, find the column with the correct manifold pressure. Then choose the desired quantity of Btu/hr. Once this is determined, read the corresponding drill number. This drill number represents the correct orifice size to be used.

The orifice guide is a quick and useful tool in determining the correct orifice size for a given gas appliance system. The orifice size can be determined if a specific consumption rate is known. Conversely, a specific consumption rate can be determined for an individual orifice size.

Malfunctions

Since the gas burner orifice is a simple device, it is frequently ignored as a source of gas appliance failures. More expensive components of a gas appliance may be diagnosed as faulty, when the source of the problem is actually a clogged orifice. Several problems may arise causing the orifice to work incorrectly:

1. The orifice may become clogged from dirt or deposits in the gas lines. The result will be a restricted or totally obstructed gas flow.

2. The orifice (all except insert-type pilot orifices) may become cross-threaded when installed. The orifice may be incorrectly aligned with the burner. The gas flow will not go straight into the burner thereby affecting the amount of air that is mixed with gas.

3. The orifice size may be incorrect. If a conversion is made from natural gas to LP-gas, the orifice size must be changed to maintain the desired heat input (Btu/hr.). The orifice size may also be too small to obtain the rated input. As a result, the gas appliance could never reach its rated Btu input.

Service Procedures

If necessary there are two methods commonly used to clean an orifice. One method is cleaning by air. This is done by blowing compressed air into the orifice or by a person blowing into the orifice with his or her mouth. A second method is cleaning by solvent. A mild solvent can be used to soak

BEST DOCUMENT AVAILABLE

the orifice once it is removed from the gas appliance. After a short soak (15-30 minutes), the orifice can be blown out with air and reinstalled.

As stated earlier, some pilot orifices have peculiar shapes ("D"-shaped or rectangular). For this reason, drilling is often impractical for a pilot orifice. If it is to be enlarged, it *must be replaced*. Cleaning pilot orifices is limited to the use of air, solvent, or small wooden toothpicks. Extreme care must be taken while cleaning pilot orifices or not only will it be enlarged, but its configuration will be changed (e.g. rounding out of a rectangular orifice). This will cause the orifice to operate incorrectly and may cause ignition problems.

If an original orifice is damaged, an orifice with an equivalent size number should be used to replace it. If the original orifice is not the correct size, a replacement orifice should be selected from the appropriate orifice guide. If a natural gas system is converted to an LP-gas system, use the correct LP-gas orifice.

Drilling

An orifice may need to be enlarged for two reasons. First, the orifice may not allow sufficient gas through to the burner, causing inefficient burning or low heat output. The old orifice can be drilled out to the size determined by using the correct orifice guide. Second, the fuel may be converted from LP-gas to natural gas. Since more natural gas is needed to provide the same appliance heat input, the original LP-gas orifice must be enlarged. The natural gas orifice guide and correct manifold pressure must be determined. Using the natural gas orifice guide, the required natural gas orifice size can be determined. When enlarging an orifice it is important that the drill be held perpendicular to the face of the orifice plug or cap so that the gas will flow straight into the burner. Burrs that may be formed by drilling should also be eliminated.

BEST DOCUMENT AVAILABLE

FIG. 1-17

NATURAL GAS ORIFICE GUIDE

PRESSURE – INCHES WATER COLUMN										
NAT. GAS: 1000 BTU/CU.FT.			1000 BTU/CU. FT.		1000 BTU/CU. FT.		1000 BTU/CU. FT.		1000 BTU/CU. FT.	
DRILL	3"		3½"		4"		5"		7"	
NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.
80	.4	400	.4	400	.5	500	.5	500	.6	600
79	.5	500	.5	500	.6	600	.6	600	.7	700
78	.6	600	.6	600	.7	700	.7	700	.9	900
77	.7	700	.7	700	.8	800	.9	900	1.1	1,100
76	.9	900	.9	900	1.0	1,000	1.2	1,200	1.4	1,400
75	1.0	1,000	1.1	1,100	1.2	1,200	1.3	1,300	1.5	1,500
74	1.1	1,100	1.2	1,200	1.3	1,300	1.5	1,500	1.8	1,800
73	1.3	1,300	1.4	1,400	1.5	1,500	1.7	1,700	2.0	2,000
72	1.4	1,400	1.5	1,500	1.6	1,600	1.8	1,800	2.2	2,200
71	1.5	1,500	1.7	1,700	1.8	1,800	2.0	2,000	2.4	2,400
70	1.8	1,800	1.9	1,900	2.1	2,100	2.3	2,300	2.7	2,700
69	1.9	1,900	2.1	2,100	2.2	2,200	2.5	2,500	3.0	3,000
68	2.2	2,200	2.3	2,300	2.5	2,500	2.8	2,800	3.4	3,400
67	2.3	2,300	2.5	2,500	2.7	2,700	3.0	3,000	3.6	3,600
66	2.5	2,500	2.7	2,700	2.9	2,900	3.2	3,200	3.8	3,800
65	2.8	2,800	3.0	3,000	3.2	3,200	3.6	3,600	4.3	4,300
64	2.9	2,900	3.1	3,100	3.4	3,400	3.8	3,800	4.5	4,500
63	3.1	3,100	3.3	3,300	3.6	3,600	4.0	4,000	4.8	4,800
62	3.3	3,300	3.6	3,600	3.8	3,800	4.2	4,200	5.0	5,000
61	3.5	3,500	3.8	3,800	4.0	4,000	4.5	4,500	5.3	5,300
60	3.6	3,600	3.9	3,900	4.2	4,200	4.7	4,700	5.7	5,700
59	3.8	3,800	4.1	4,100	4.4	4,400	5.0	5,000	6.1	6,100
58	4.0	4,000	4.4	4,400	4.7	4,700	5.3	5,300	6.4	6,400
57	4.3	4,300	4.7	4,700	5.1	5,100	5.7	5,700	6.8	6,800
56	5.1	5,100	5.6	5,600	6.0	6,000	6.8	6,800	8.0	8,000
55	6.2	6,200	6.9	6,900	7.5	7,500	8.5	8,500	10	10,000
54	7.4	7,400	8.2	8,200	9.0	9,000	10	10,000	12	12,000
53	9.0	9,000	9.5	9,500	10	10,000	11	11,000	13	13,000
52	10	10,000	11	11,000	12	12,000	13	13,000	15	15,000
51	11	11,000	12	12,000	13	13,000	15	15,000	17	17,000

BEST DOCUMENT AVAILABLE

NATURAL GAS ORIFICE GUIDE

PRESSURE – INCHES WATER COLUMN										
NAT. GAS: 1000 BTU/CU.FT.			1000 BTU/CU. FT.		1000 BTU/CU. FT.		1000 BTU/CU. FT.		1000 BTU/CU. FT.	
DRILL	3"		3½"		4"		5"		7"	
NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.
50	12	12,000	13	13,000	14	14,000	16	16,000	19	19,000
49	14	14,000	15	15,000	16	16,000	18	18,000	21	21,000
48	15	15,000	16	16,000	17	17,000	19	19,000	22	22,000
47	16	16,000	17	17,000	18	18,000	20	20,000	24	24,000
46	17	17,000	18	18,000	19	19,000	22	22,000	26	26,000
45	18	18,000	19	19,000	20	20,000	23	23,000	27	27,000
44	19	19,000	21	21,000	22	22,000	25	25,000	29	29,000
43	20	20,000	22	22,000	23	23,000	26	26,000	31	31,000
42	22	22,000	24	24,000	26	26,000	29	29,000	35	35,000
41	24	24,000	25	25,000	27	27,000	31	31,000	36	36,000
40	25	25,000	26	26,000	28	28,000	32	32,000	38	38,000
39	26	26,000	28	28,000	30	30,000	33	33,000	39	39,000
38	27	27,000	29	29,000	31	31,000	34	34,000	41	41,000
37	28	28,000	30	30,000	32	32,000	36	36,000	43	43,000
36	30	30,000	32	32,000	34	34,000	38	38,000	45	45,000
35	31	31,000	33	33,000	36	36,000	40	40,000	48	48,000
34	32	32,000	34	34,000	37	37,000	41	41,000	49	49,000
33	33	33,000	36	36,000	38	38,000	43	43,000	51	51,000
32	35	35,000	38	38,000	40	40,000	45	45,000	54	54,000
31	37	37,000	40	40,000	43	43,000	48	48,000	57	57,000
30	43	43,000	46	46,000	50	50,000	56	56,000	66	66,000
29	48	48,000	51	51,000	55	55,000	62	62,000	73	73,000
28	51	51,000	55	55,000	59	59,000	66	66,000	79	79,000
27	54	54,000	58	58,000	62	62,000	70	70,000	83	83,000
26	56	56,000	61	61,000	65	65,000	73	73,000	87	87,000
25	58	58,000	63	63,000	67	67,000	75	75,000	89	89,000
24	60	60,000	65	65,000	69	69,000	78	78,000	92	92,000
23	62	62,000	67	67,000	71	71,000	80	80,000	94	94,000
22	64	64,000	69	69,000	74	74,000	83	83,000	98	98,000
21	66	66,000	71	71,000	76	76,000	85	85,000	100	100,000

BEST DOCUMENT AVAILABLE

NATURAL GAS ORIFICE GUIDE

PRESSURE – INCHES WATER COLUMN										
NAT. GAS: 1000 BTU/CU.FT.			1000 BTU/CU. FT.		1000 BTU/CU. FT.		1000 BTU/CU. FT.		1000 BTU/CU. FT.	
DRILL	3"		3½"		4"		5"		7"	
NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.
20	68	68,000	73	73,000	78	78,000	87	87,000	103	103,000
19	72	72,000	77	77,000	83	83,000	93	93,000	110	110,000
18	75	75,000	81	81,000	87	87,000	97	97,000	115	115,000
17	78	78,000	84	84,000	90	90,000	101	101,000	119	119,000
16	82	82,000	88	88,000	94	94,000	105	105,000	125	125,000
15	84	84,000	90	90,000	97	97,000	109	109,000	129	129,000
14	86	86,000	93	93,000	100	100,000	112	112,000	132	132,000
13	89	89,000	96	96,000	103	103,000	115	115,000	137	137,000
12	93	93,000	100	100,000	108	108,000	121	121,000	143	143,000
11	95	95,000	102	102,000	110	110,000	123	123,000	146	146,000
10	97	97,000	105	105,000	113	113,000	126	126,000	149	149,000
9	100	100,000	108	108,000	116	116,000	130	130,000	153	153,000
8	103	103,000	111	111,000	119	119,000	133	133,000	158	158,000
7	105	105,000	113	113,000	122	122,000	136	136,000	161	161,000
6	108	108,000	117	117,000	125	125,000	140	140,000	166	166,000
5	110	110,000	119	119,000	127	127,000	142	142,000	168	168,000
4	114	114,000	123	123,000	132	132,000	147	147,000	174	174,000
3	118	118,000	127	127,000	137	137,000	153	153,000	181	181,000
2	128	128,000	138	138,000	148	148,000	165	165,000	195	195,000
1	136	136,000	147	147,000	157	157,000	175	175,000	207	207,000

BEST DOCUMENT AVAILABLE

FIG. 1-18

LP GAS ORIFICE GUIDE (BUTANE)

PRESSURE – INCHES WATER COLUMN					PRESSURE – INCHES WATER COLUMN				
BUTANE – 3010 BTU/CU. FT.			3280 BTU/CU. FT.		BUTANE – 3010 BTU/CU. FT.			3280 BTU/CU. FT.	
DRILL	10½"		11"		DRILL	10½"		11"	
NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.
80	.46	1,382	.48	1,590	49	13.38	40,274	13.83	45,350
79	.52	1,565	.56	1,830	48	14.50	43,645	15.34	50,300
78	.64	1,926	.68	2,230	47	15.42	46,414	16.33	53,550
77	.80	2,408	.86	2,815	46	16.46	49,545	17.38	57,000
76	.96	2,890	1.06	3,480	45	16.95	51,020	17.84	58,500
75	1.10	3,311	1.17	3,840	44	18.48	55,625	19.62	64,350
74	1.27	3,823	1.34	4,410	43	19.92	59,959	21.04	69,000
73	1.43	4,304	1.52	5,010	42	22.05	66,371	23.23	76,200
72	1.56	4,692	1.66	5,450	41	23.01	69,260	24.45	80,200
71	1.68	5,057	1.80	5,900	40	23.96	72,119	25.46	83,500
70	1.95	5,870	2.08	6,830	39	24.59	74,015	26.28	86,200
69	2.13	6,411	2.27	7,430	38	25.53	76,845	27.30	89,550
68	2.40	7,224	2.55	8,370	37	25.85	77,808	28.66	94,000
67	2.58	7,766	2.72	8,910	36	28.37	85,393	30.12	98,800
66	2.74	8,247	2.89	9,470	35	30.26	91,082	32.10	105,300
65	3.08	9,241	3.25	10,670	34	30.57	92,015	32.68	107,200
64	3.25	9,782	3.45	11,300	33	31.83	95,808	34.12	111,900
63	3.45	10,385	3.63	11,900	32	33.41	100,564	35.67	117,000
62	3.62	10,896	3.82	12,530	31	35.93	108,149	38.23	125,400
61	3.81	11,768	4.05	13,280	30	40.98	123,349	43.78	143,600
60	4.03	12,130	4.22	13,840	29	46.02	138,520	49.82	163,400
59	4.22	12,702	4.46	14,630	28	49.18	148,032	52.32	171,600
58	4.45	13,394	4.66	15,300	27	51.69	155,586	54.88	180,000
57	4.62	13,906	4.91	16,090	26	53.90	162,239	57.29	187,900
56	5.40	16,254	5.73	18,790	25	55.70	167,928	59.33	194,600
55	6.81	20,498	7.17	23,510	24	57.69	173,647	61.46	201,600
54	7.60	22,876	8.02	26,300	23	58.94	177,409	62.93	206,400
53	8.91	26,819	9.40	30,830	22	61.47	185,025	65.40	214,500
52	10.10	30,401	10.70	35,100	21	62.41	187,854	67.13	220,200
51	11.24	33,832	12.01	39,400	20	64.62	194,566	68.60	225,000
50	12.34	37,143	13.05	42,800					

BEST DOCUMENT AVAILABLE

FIG. 1-19

LP GAS ORIFICE GUIDE (PROPANE)

PRESSURE – INCHES WATER COLUMN					PRESSURE – INCHES WATER COLUMN				
PROPANE – 2500 BTU/CU. FT.			2516 BTU/CU. FT.		PROPANE – 2500 BTU/CU. FT.			2516 BTU/CU. FT.	
DRILL	10½"		11"		DRILL	10½"		11"	
NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.	NO.	CU.FT./HR.	BTU/HR.	CU.FT./HR.	BTU/HR.
80	.49	1,250	.57	1,430	49	14.45	36,848	16.63	41,850
79	.57	1,454	.66	1,655	48	15.70	40,035	18.10	45,540
78	.69	1,760	.80	2,015	47	16.78	42,789	19.24	48,400
77	.87	2,219	1.01	2,545	46	17.75	45,263	20.47	51,500
76	1.06	2,703	1.24	3,140	45	18.31	46,961	21.03	52,900
75	1.20	3,060	1.38	3,465	44	20.10	51,255	23.07	58,050
74	1.37	3,494	1.60	3,985	43	21.55	54,953	24.72	62,200
73	1.56	3,978	1.80	4,525	42	23.87	60,869	27.31	68,700
72	1.70	4,335	1.96	4,920	41	25.06	62,650	28.80	72,450
71	1.83	4,667	2.11	5,320	40	26.09	65,225	29.96	75,400
70	2.14	5,457	2.46	6,180	39	26.78	66,950	30.94	77,850
69	2.31	5,891	2.67	6,710	38	27.81	69,525	32.19	81,000
68	2.60	6,630	3.00	7,560	37	29.18	72,950	33.78	85,000
67	2.78	7,089	3.12	8,040	36	30.89	77,225	35.45	89,200
66	2.97	7,574	3.40	8,550	35	32.95	82,375	37.75	95,000
65	3.35	8,543	3.83	9,630	34	33.30	83,250	38.55	97,000
64	3.52	8,976	4.05	10,200	33	34.67	86,675	40.14	101,000
63	3.72	9,486	4.29	10,800	32	36.39	91,725	42.05	105,800
62	3.92	9,996	4.51	11,360	31	39.13	97,825	44.99	113,200
61	4.15	10,583	4.74	11,930	30	44.62	111,550	51.55	129,700
60	4.35	11,093	5.00	12,570	29	50.12	125,300	57.91	145,700
59	4.57	11,654	5.25	13,220	28	53.55	133,875	61.49	154,700
58	4.80	12,240	5.54	13,840	27	56.30	140,750	64.83	163,100
57	5.08	12,954	5.78	14,550	26	58.70	146,750	67.53	169,900
56	5.90	15,045	6.75	16,990	25	60.76	151,900	69.75	175,500
55	7.37	18,794	8.43	21,200	24	62.82	157,050	72.22	181,700
54	8.23	20,987	9.48	23,850	23	64.19	160,475	74.24	186,800
53	9.61	24,506	11.05	27,790	22	66.94	167,350	76.91	193,500
52	10.92	27,835	12.61	31,730	21	67.67	169,925	78.93	198,600
51	12.23	31,187	14.04	35,330	20	70.37	175,925	80.96	203,700
50	13.32	33,966	15.30	38,500					

BEST DOCUMENT AVAILABLE

FIG. 1-20

STANDARD TWIST DRILL SIZES

NOTE: DESIGNATIONS ARE IN STANDARD TWIST DRILL NUMBERS ONLY

DESIGNATION	DIAM. INCH	DESIGNATION	DIAM. INCH	DESIGNATION	DIAM. INCH
1	.228	28	.1405	55	.0520
2	.221	29	.1360	56	.0465
3	.213	30	.1285	57	.0430
4	.209	31	.1200	58	.0420
5	.2055	32	.1160	59	.0410
6	.204	33	.1130	60	.0400
7	.201	34	.1110	61	.039
8	.199	35	.1100	62	.038
9	.196	36	.1065	63	.037
10	.1935	37	.1040	64	.036
11	.191	38	.1015	65	.035
12	.189	39	.0995	66	.033
13	.185	40	.0980	67	.032
14	.182	41	.0960	68	.031
15	.1800	42	.0935	69	.0292
16	.1770	43	.0890	70	.028
17	.1730	44	.0860	71	.026
18	.1695	45	.0820	72	.025
19	.1660	46	.0810	73	.024
20	.1610	47	.0785	74	.0225
21	.1590	48	.0760	75	.021
22	.1570	49	.0730	76	.020
23	.1540	50	.0700	77	.018
24	.1520	51	.0670	78	.016
25	.1495	52	.0635	79	.0145
26	.1470	53	.0595	80	.0135
27	.1440	54	.0550		

BEST DOCUMENT AVAILABLE

SECTION 2

GAS COMBUSTION FUNDAMENTALS

FUEL COMBUSTION CHARACTERISTICS

Combustion will occur if fuel and oxygen are heated to the temperature at which ignition will occur. The *combustion triangle* shown in Figure 2-1 illustrates this relationship. Remove either fuel, oxygen, or heat and combustion will cease.

In heating appliances, the fuel is normally natural gas or LP-gas. Air supplies the required oxygen. Since only about 20% of air is oxygen, 80% of the air supplied (mostly nitrogen) does not contribute to the combustion process. Finally, the heat is required by some type of ignition device, such as a pilot flame.

Characteristics of Combustion

Since combustion is a chemical reaction between a fuel gas and oxygen, the ideal ratio of gas to oxygen can be accurately determined for any specific fuel gas. *Combustion ratios* for natural gas and LP-gas are shown in Figure 2-2. At these ratios of fuel to air, combustion will be complete and a maximum amount of heat will be produced.

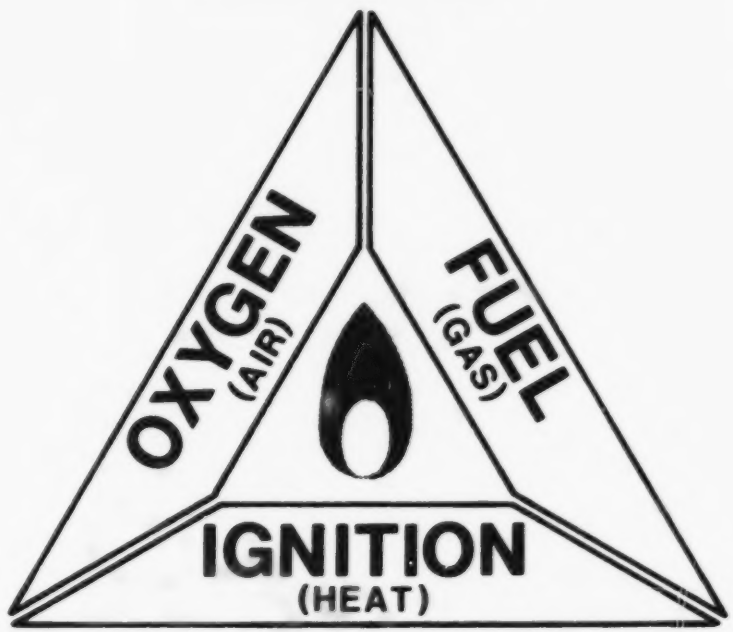
Within certain limits, less efficient combustion will occur at fuel to air ratios that are higher and lower than the ideal. These limits are called *flammability limits* and are shown in Figure 2-2 for natural gas and LP-gas. Mixtures of fuel and air outside the *flammability limits* are either too lean (too little fuel) or too rich (too much fuel) to ignite.

The *combustion ratio* assumes an ideal condition in which all of the oxygen in the air is utilized in combustion. In actual practice, this ideal condition does not occur. Therefore, additional air must be supplied to insure the oxygen required for combustion will be available. This additional air is called *excess air*.

The *ignition temperature* of a gas is the minimum temperature at which combustion of a fuel-air mixture will occur. Values for natural gas and LP-gases are given in Figure 2-2. This burning temperature will depend on air supply, physical arrangement of the burner, and other factors. Heating appliances are designed to maintain burning temperatures higher than the ignition temperature so that once ignited, the fuel-air mixture will continue to burn completely.

FIG. 2-1

COMBUSTION TRIANGLE



Products of Combustion

Combustion is a chemical reaction in which fuel gases (hydrocarbons) combine with oxygen and are ignited. Energy, as heat, is released in the process and certain by-products are formed from the combustion process. Hydrogen from the fuel gas combines with oxygen to form water vapor (H_2O). Oxygen also combines with carbon from the fuel gas to form oxides of carbon (CO_2 and CO). Nitrogen in the air supply passes through the combustion process virtually unchanged.

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

FIG. 2-2

PETROLEUM GAS CHARACTERISTICS

CHARACTERISTIC	NATURAL GAS	PROPANE GAS	BUTANE GAS
FORMULA	CH_4 (90%)	C_3H_8	C_4H_{10}
SPECIFIC GRAVITY (AIR = 1.00)	.64	1.53	2.00
IGNITION TEMPERATURE (IN AIR)	1100-1200°F	920-1020° F	900-1000° F
MAXIMUM FLAME TEMPERATURE (IN AIR)	3400° F	3595° F	3615° F
COMBUSTION RATIO (CU.FT. AIR/CU.FT. GAS)	10	24	31
BOILING POINT (ATM. PR.)	–260° F	–44° F	30° F
FLAMMABILITY LIMITS (UPPER)	14%	9.5%	8.4%
FLAMMABILITY LIMITS (LOWER)	4%	2.1%	1.8%
HEATING VALUE (BTU/CU.FT.)	900-1200	2500	3010
OPERATING PRESSURES			
MAINLINE	5-60 PSI	NOT APPLICABLE	NOT APPLICABLE
SERVICE	3-15" W.C.	11-15 PSI	11-15 PSI
APPLIANCE	3-7" W.C.	10-14" W.C.	10-14" W.C.

The exact nature and make-up of the combustion products depend on both the fuel-air ratio and the conditions under which combustion takes place.

The amount of heat released is the *heating value* of the fuel gas and is expressed in Btu's per cubic foot of fuel gas. Heating values for natural gas and LP-gases are shown in Figure 2-2. The maximum flame temperatures (based on air as the source of oxygen) are also shown in Figure 2-2.

Complete combustion of fuel gases in heating appliances occurs when excess air is supplied to insure adequate oxygen. Water vapor and carbon dioxide are produced and the full heat value of the fuel gas is released. Complete combustion utilizes fuel gases efficiently and creates harmless products from the process.

If the supply of excess air is insufficient, or if the air supply has a less than normal oxygen content, oxygen supply will be inadequate and incomplete combustion will result. This will produce more carbon monoxide instead of carbon dioxide. Incomplete combustion produces less than the full heat value of the gas. Harmful products of incomplete combustion include carbon monoxide, aldehydes, hydrogen, and soot.

Carbon monoxide is highly toxic in concentrations of greater than .04% in air. It has no odor, color or taste. It is flammable and explosive in a wide range of mixtures with air. Since it is toxic at very low concentrations, its toxic effects are a much more serious problem than the chance of explosion. Toxic effects are shown in Figure 2-2A for various concentrations and exposure durations.

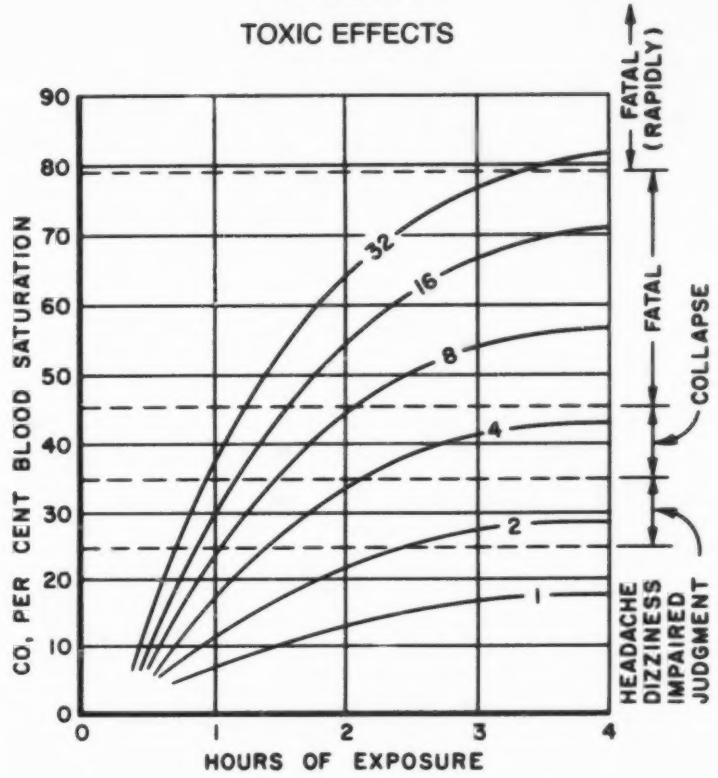
Aldehydes are toxic combustion products which have a sharp penetrating odor and are readily detectable. If aldehydes are present, carbon monoxide will almost always be present, too. The absence of aldehydes does not, however, assure the absence of carbon monoxide.

BURNERS

Gas burners control the mixing of air and gas for combustion and determine the character and shape of the flame. *Aerated* burners mix air with gas prior to discharging it for combustion. *Nonaerated* burners discharge the gas for combustion without premixing it with air.

BEST DOCUMENT AVAILABLE

FIG. 2-2A



A nonaerated burner is simply a passageway which discharges gas at one or more ports. A single port nonaerated burner is shown in Figure 2-3. Oxygen required for combustion is supplied from the surrounding air and is called secondary air. Unburned carbon is formed which glows yellow as it passes through the outer portion of the flame. For this reason, nonaerated burners are often called *luminous flame* burners, or *yellow flame* burners.

Air supplied to the flame of a nonaerated burner can be improved by reducing the size of the burner ports. Since the diameter of the gas stream being discharged is reduced, the interior zone of the flame, where combustion is incomplete, is reduced. When properly designed and operated at very low gas flow rates, this type of burner can produce a flame which is blue or blue with yellow tips.

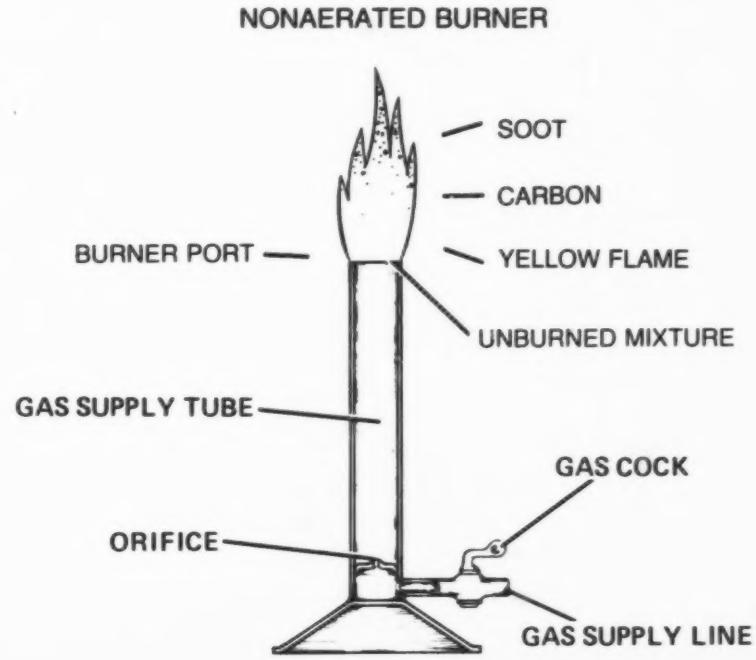
Aerated burners mix air with gas prior to discharging it at the burner port for combustion. This type of burner was invented about 1855 by Robert Wilhelm von Bunsen and is often called a *Bunsen* or *blue flame* burner. Aerated burners provide complete combustion of fuel gases over a wide range of gas pressures and flow rates.

A single port aerated laboratory burner is shown in Figure 2-4. Gas enters through an orifice at the base of the burner. Air enters through an adjustable opening and mixes with the gas as it travels upward through the burner body. Combustion of the fuel-air mixture occurs at the burner port.

An aerated burner flame has several combustion zones. These zones are also shown in Figure 2-4. On the tip of the burner port is a thin blue cone called the inner or primary cone. Inside the inner cone is a darker area of unburned, fairly cool air-gas mixture. This mixture begins to burn at the inner cone, forming intermediate products such as aldehydes, alcohols, carbon monoxide, and hydrogen. Complete combustion of these intermediate products occurs in the darker, outer cone. The surrounding air enters the combustion process in this outer cone, providing sufficient air for complete combustion. An outer mantle forms around the outer cone. Although no combustion occurs in this mantle, it may glow because of the high temperature of the combustion products and illuminated particles passing through the flame.

Air mixed with gas prior to exiting the burner port is called *primary* air. Aerated burners generally provide a way to adjust the flow of *primary* air to achieve the desired flame characteristics. Additional air required for combustion enters the flame from the area around the burner. The

FIG. 2-3



additional air is called *secondary* air. Both aerated and nonaerated burners utilize secondary air. The effectiveness of an aerated burner can be improved if *primary* air and the fuel gas are thoroughly mixed prior to being discharged for combustion. The aerated burner shown in Figure 2-4 has a simple burner body which allows, but does not force the gas and air to mix. This is referred to as a "free mixing" atmospheric burner. Most heating appliance main burners incorporate a *venturi* similar to the one shown in Figure 2-5 to improve mixing. The *venturi* is a smooth constriction or throat which forces the air-gas mixture to accelerate and then quickly decelerate. The turbulence created effectively mixes the air and gas, evenly distributing the fuel-air mixture for combustion.

PILOT BURNERS

The pilot burner ignites the gas supply at the appliance main burner(s). In addition, pilot burners frequently provide the heat energy required to activate automatic safety devices. Unless the pilot is ignited, the safety

FIG. 2-4

TYPICAL BUNSEN BURNER AND FLAME

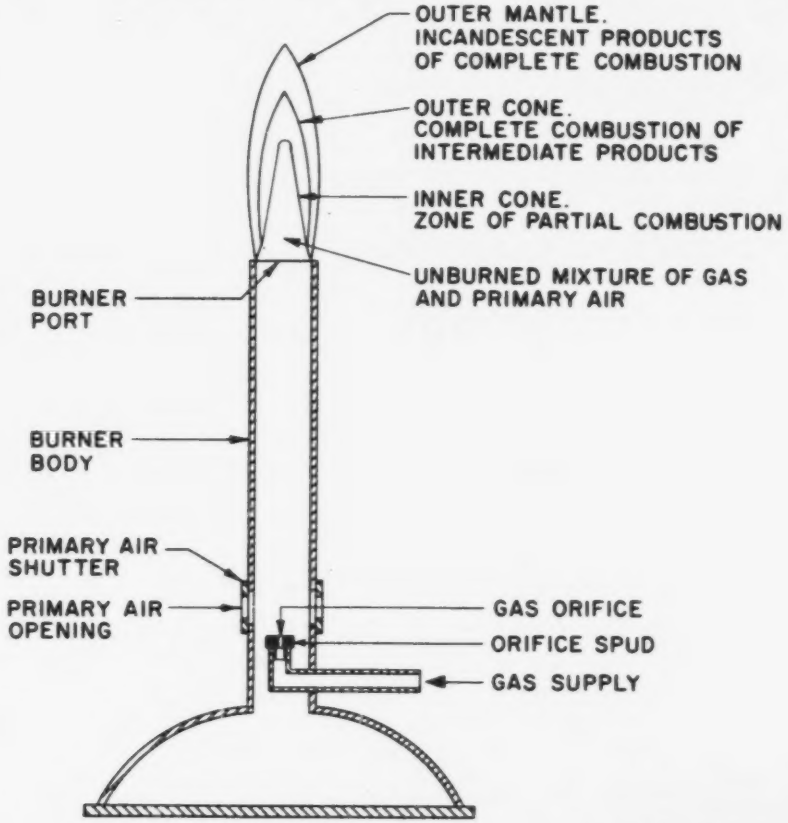
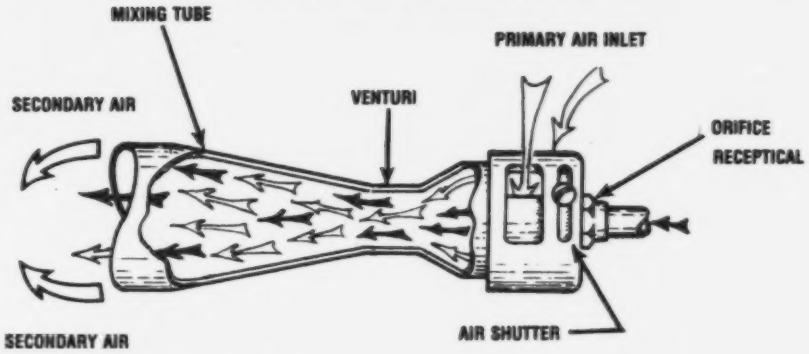


FIG. 2-5

ATMOSPHERIC MAIN BURNER

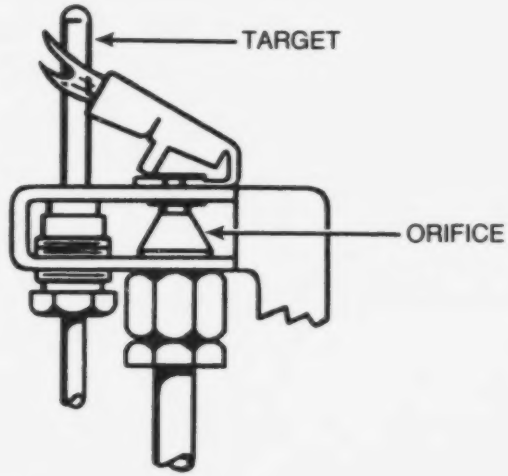


device will stop the flow of gas to the main burners. Pilots which ignite more than one main burner use a carry over slot to "carry over" the flame from one burner to the other. The plugging-up of this slot is a common source of delayed ignition or failure of the safety device.

Target-type pilot burners are nonaerated burners that direct the gas stream toward a target, such as a main burner or safety device. The surrounding air mixes with the gas before it reaches the target device where combustion occurs. Mixing of air with the gas is normally adequate to provide a blue flame. This type of pilot burner is shown in Figure 2-6.

FIG. 2-6

TARGET — TYPE PILOT



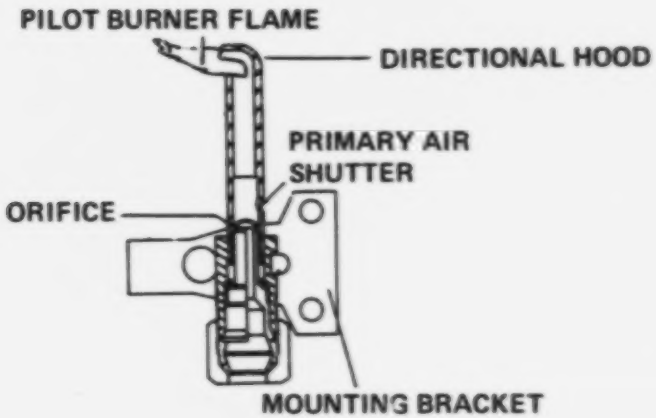
BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

Aerated pilot burners are small Bunsen burners that have an orifice, gas supply connection, mixing tube, primary air opening, and directional hood. Most aerated pilot burners have a single port. The air shutter or opening is normally located in the side of the supply/mixing tube just above the orifice. The directional hood can be designed to direct the flame in one direction (unidirectional) or several directions (multidirectional). Figure 2-7 shows an aerated pilot burner with insert-type orifice, fixed air inlet, and unidirectional hood.

FIG. 2-7

AERATED PILOT BURNER



The air inlet in an aerated pilot burner is subject to blockage by dust, lint, insects, and other foreign material. The incinerator-type pilot burner, shown in Figure 2-8, overcomes this problem by drawing primary air through an air intake located near the pilot burner flame. This action incinerates any dust or lint which may be mixed with the primary air supply.

Pilot burners are often equipped with directional hoods which direct the flame toward the main burner or safety device, or to both. Figure 2-9 shows flame patterns for a unidirectional hood and for 2-way and 3-way multidirectional hoods. Multidirectional hoods are used where the pilot flame must be directed in several different directions to ignite main burners or heat a safety device.

Gas input rates of pilot burners vary widely. The input rate depends entirely on the type of pilot burner and the style of appliance in which it is used. Input rates for heating appliance burners frequently range between 500 and 1,500 Btu's per hour. Pilot burners generally should burn with a fairly soft blue flame with little or no yellow-tipping (see Figure 2-10), pilot burners which burn with a slightly yellow flame are an exception.

FIG. 2-8

INCINERATOR TYPE PILOT

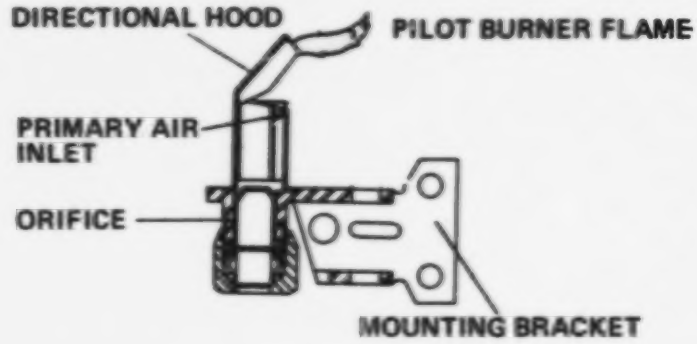


FIG. 2-9

DIRECTIONAL PILOT BURNERS

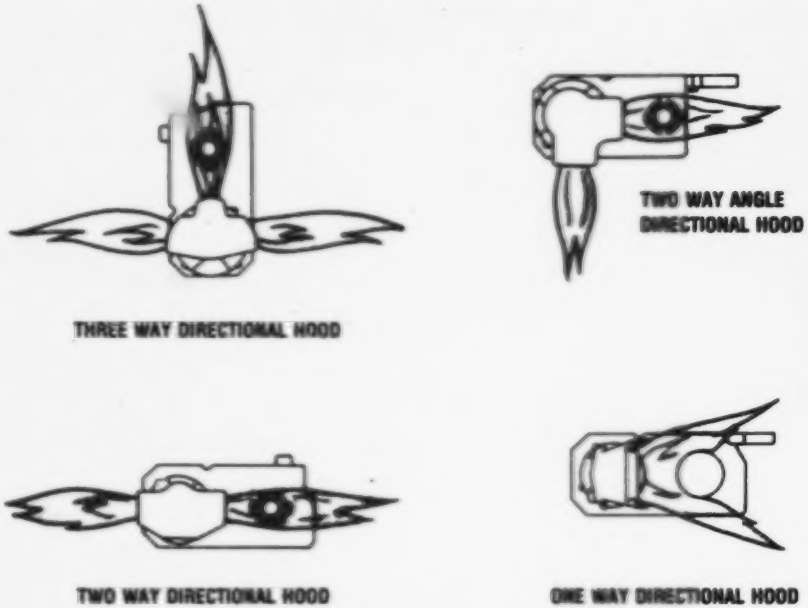
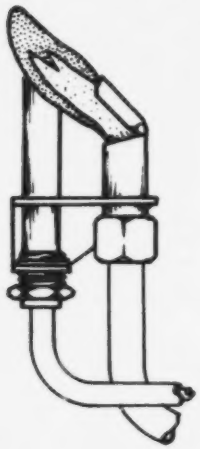


FIG. 2-10

PROPER PILOT FLAME



CHARACTERISTICS

1. CORRECT AIR-GAS MIXTURE
2. BLUE COLOR
3. WELL DEFINED
4. EFFICIENT COMBUSTION

Malfunctions and Servicing

Proper servicing of burners is essential to prevent appliance malfunctions and to insure reliable efficient performance. The most common problem associated with pilot burners is clogging by dust or debris from the air supply. The relatively small pilot orifices make them susceptible to blockage. Careful cleaning of the orifice may correct this problem. If this proves ineffective, the orifice may need to be replaced.

Aerated pilot burners are also especially susceptible to blockage of the primary air inlet or shutter. Foreign material may enter the burner through the air shutter and clog the burner tube. Disassembling and blowing air through the burner may correct the problem. If the problem cannot be corrected, the pilot burner assembly should be replaced. Make certain that the main burner carryover slots are also free from foreign material.

If a pilot burner malfunctions, it generally fails to ignite the main burner or fails to heat the safety device. The burner may burn too hot and damage the safety device sensor, or it may be excessively noisy. Some malfunctions may not significantly affect appliance operation. In any case, pilot burner malfunction can normally be detected by observing the flame characteristics. Characteristics of improper pilot flames are shown in Figure 2-11 for aerated pilot burners, with possible causes and corrective actions.

MAIN BURNERS

The main burner is the heart of a heating appliance. It controls the mixing of air and gas for combustion and determines the size, shape, and nature of the flame. The efficiency of the heating appliance depends in large measure on how effectively the main burner operates.

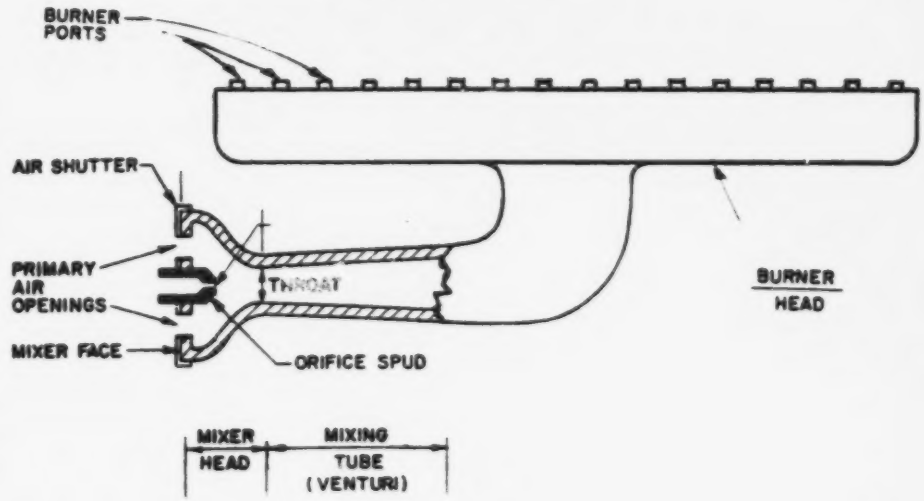
In heating appliances, the main burner is almost always of the aerated-type because the use of primary air improves efficiency and makes the burner adaptable to a wide range of applications. For this reason, this discussion of main burners will be limited to the aerated-type.

Aerated main burners are manufactured in a variety of shapes and sizes but all have four major component parts: an orifice receptacle, a primary air inlet with shutter, a mixing tube and venturi, and a burner head and/or ports where combustion takes place. A typical main burner is shown in Figure 2-12.

The orifice is normally located at or near the gas supply connection. It controls and directs the flow of gas into the burner.

FIG. 2-12

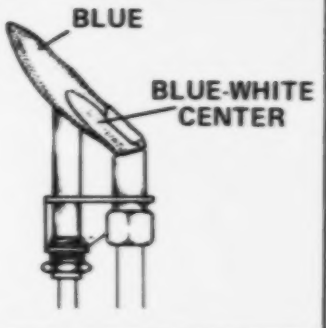
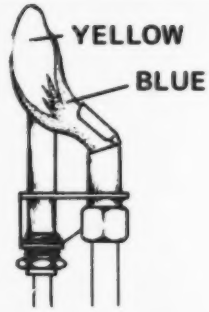
TYPICAL MAIN BURNER



BEST DOCUMENT AVAILABLE

FIG. 2-11

IMPROPER PILOT FLAMES

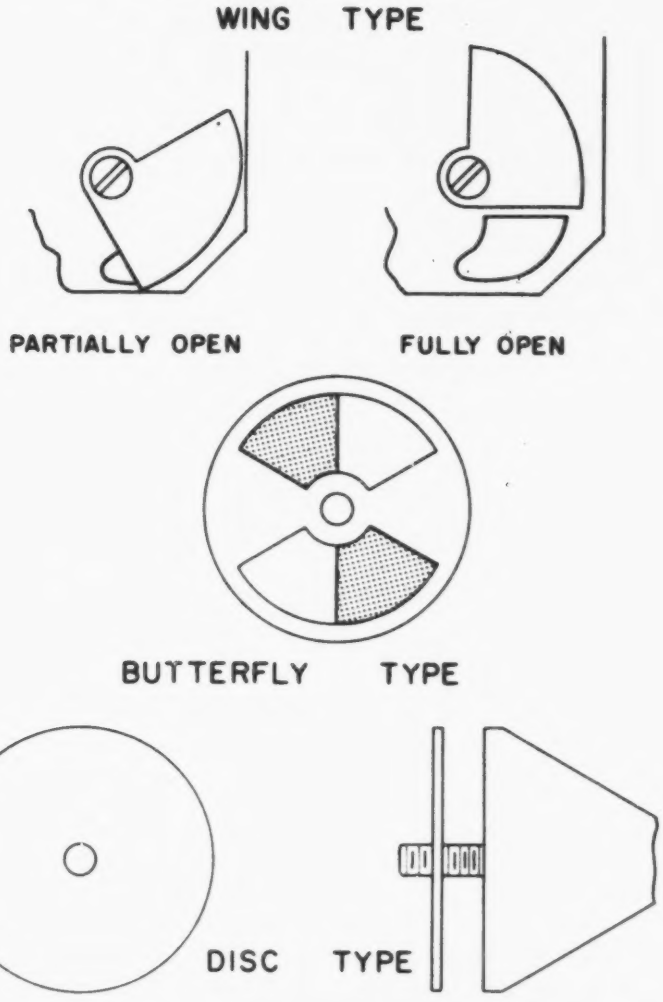
HARD/SHARP FLAME	LIFTING/BLOWING FLAME	SMALL/LAZY FLAME	YELLOW FLAME
1 	2	3	4 
POSSIBLE CAUSES:	**POSSIBLE CAUSES:**	**POSSIBLE CAUSES:**	**POSSIBLE CAUSES:**
1. Excess Of Primary Air.	1. Gas Pressure Too High. 2. Secondary Air Supply Too High. Excess Cross Draft In Burner Area.	1. Clogged Burner Orifice. 2. Burner Orifice Too Small. 3. Restricted Pilot Supply Line. 4. Insufficient Gas Pressure	1. Orifice Too Large. 2. Primary Air Shutter Clogged.
CORRECTIVE ACTION:	**CORRECTIVE ACTION:**	**CORRECTIVE ACTION:**	**CORRECTIVE ACTION:**
1. Adjust Primary Air Shutter.	1. Check Gas Pressure With Manometer. Adjust If Necessary. 2. Reduce Secondary Air Supply, If Applicable. Eliminate Cross Draft.	1. Clean/Ream Burner Orifice. Replace If Necessary. 2. Replace Burner Orifice. 3. Remove Pilot Supply Line And Clean. Replace If Necessary. 4. Adjust Pressure As Necessary.	1. Replace Burner Orifice. 2. Clean Primary Air Shutter. Replace Burner If Necessary.

BEST DOCUMENT AVAILABLE

The air shutter opening admits primary air to the burner and is normally adjustable to regulate its flow. Wing, butterfly, and rotating disc type air shutters are shown in Figure 2-13. A second method of regulating air flow is the installation of a turbulating screw in the throat of the main burner. The mixing tube directs the air and gas to the burner head and provides for mixing along the way. Most heating appliance main burners have a venturi throat built into the mixing tube to improve mixing and maintain a more constant flow of primary air.

FIG. 2-13

AIR SHUTTER TYPES



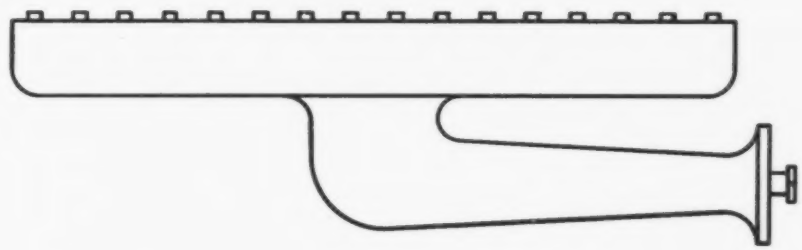
The burner head contains the burner ports and provides uniform distribution of the air-gas mixture to these ports. Its size and shape are designed to provide the specific size, shape, and type of flame characteristics. Multiple ports are normally used in order to provide good exposure of the flames to secondary air, to distribute the flames for good heat transfer, and to provide stable, blue flames.

Heating appliance main burners vary greatly in size and shape. For this reason they are classified according to their port design; *drilled* port, *slotted* port, or *ribbon* port.

Drilled port burners have a number of separate, relatively small circular ports created by drilling the burner head. Formed, pierced, or punched ports of oval-like cross section behave like drilled ports and are often referred to as drilled ports even though not made by drilling. Drilled ports are used in cast and stamped sheet metal burner bodies. Cast metal burners often have raised flat portions called bosses through which the burner ports are drilled. Bosses provide good port depth without requiring thick burner walls. Drilled port burners are manufactured in a wide variety of shapes and materials. A cast-iron drilled port burner is shown in Fig. 2-14.

FIG. 2-14

CAST-IRON MAIN BURNER



Ports in slotted port burners are formed by sawing, stamping, or punching long narrow slots in the burner body or by dividing a large opening in the burner body with flat strips of metal spaced to form slots. A stamped sheet metal slotted port burner is shown in Fig. 2-15. The design of slotted port burners is economical and lends itself to stamped sheet metal construction.

In ribbon port burners, alternating flat and corrugated strips of stainless steel strips are sandwiched together to form the ribbon port assembly.

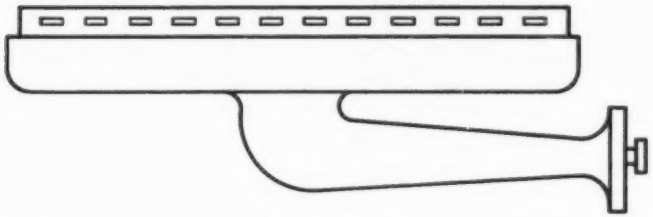
This assembly is then installed in an opening in the burner head as shown in Figure 2-16. The result is a burner with a large number of relatively

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

FIG. 2-15

METAL SLOTTED PORT BURNER



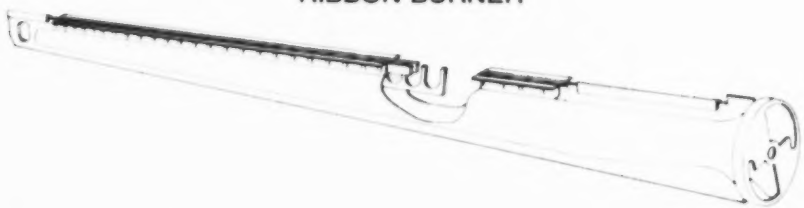
small, deep and closely spaced ports. Ribbon-type ports are used in bar-type and round burners with vertical flame patterns.

Monoport burners, as the name implies, utilize one burner port. The burner is constructed of an air shutter, venturi, mixing tube, and a large single burner port. Normally, a cone-shaped deflector is attached above the burner port. The deflector acts to evenly direct or spread the main burner flame. This spreading action helps to mix secondary air with the fuel gas mixture prior to combustion. A monoport burner is shown in Figure 2-17.

Other types of burner ports used in heating appliances include jet burners, radiant burners, and impingement target burners. These burner designs are not as widely used in heating appliances as are drilled, slotted, and ribbon port burners.

FIG. 2-16

RIBBON BURNER

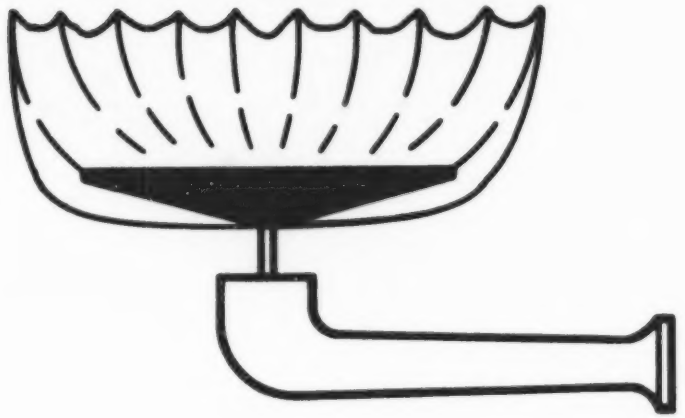


Burner Operation

Aerated heating appliance burners can be classified as *atmospheric* burners or *power* burners, based on how primary and/or secondary air is supplied. In atmospheric burners, primary air is brought into the burner at atmospheric pressure. In power burners, pressure of the gas or air, or both, is boosted by mechanical power (pump or blower). Power burners are used for many purposes such as conversion burners in homes and in numerous industrial applications. The following discussion of burner operations is

FIG. 2-17

MONOPORT BURNER



concerned primarily with atmospheric burners, but with careful consideration of the differences, the basic principles are also applicable to the operation of power burners.

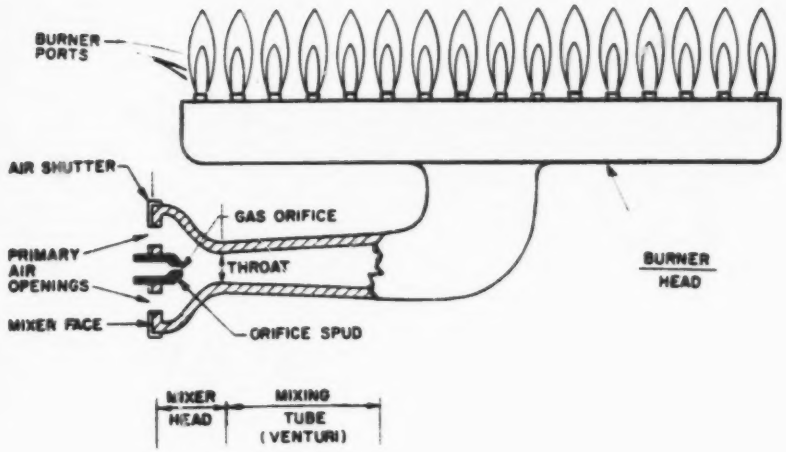
Figure 2-18 shows an aerated main burner with gas supply orifice, primary air shutter, mixing tube with venturi, and burner ports. Fuel gas is supplied to the burner at a regulated pressure. Orifice size and gas manifold pressure establish the gas flow rate. The orifice acts as a nozzle, directing and metering a stream of fuel gas into the center of the venturi. This high velocity gas jet flowing through the narrow throat of the venturi reduces in pressure. Air flows through the air inlet toward this area of low pressure and is drawn into the gas stream.

The amount of primary air drawn into the burner is controlled with the primary air shutter. Additional primary air can be drawn into the burner by increasing the velocity of the gas stream. For example, if a smaller gas orifice is used and gas pressure is increased to maintain the same heat input rate (cubic feet of gas per hour), the velocity of the gas through the orifice is higher and the flow of primary air increases. In most cases, the result is a leaner flame.

After passing through the venturi throat, the air and gas mix in the mixing tube and flow out of the burner ports, where the mixture is ignited. The ports act as a restriction to flow and, by affecting the pressure in the venturi, have an effect on primary air flow. Fewer, smaller ports produce higher pressures at the venturi and less primary air enters the gas stream. More numerous, larger ports allow the air-gas mixture to flow freely

FIG. 2-18

AERATED MAIN BURNER



through the burner, producing lower pressures at the venturi and increasing primary air flow. Blockage of port openings can restrict the flow and decrease primary air flow. Other restrictions to the air-gas mixture, such as internal roughness of the burner throat or blockage by foreign material, will also affect the flow of primary air.

Combustion of the air-gas mixture occurs at the ports. Secondary air is drawn from around the burner to supply sufficient oxygen for complete combustion to occur. Well designed, properly operating burners incorporate these characteristics: 1) good control of primary air, 2) thorough mixing of the air-gas mixture, 3) even distribution of the mixture to the ports, 4) adequate exposure of all flames to secondary air, and 5) rapid, quiet ignition of flame from port to port on ignition.

The resulting flame exhibits the characteristics described earlier for aerated burners with inner cone, outer cone, and mantle. The outer edge of the flame base is located slightly above the port level. The flame is soft but well-defined, blue in color without yellow tipping, quiet, and uniform in size, color and character over all burner ports. These flame characteristics are shown in Figure 2-19.

Providing the input to the gas appliance burner is correct, proper flame characteristics can usually be obtained by adjusting primary air to give a soft blue flame having luminous tips and then increasing the primary air opening to a point where the yellow tips just disappear.

Malfunctions

Most main burner malfunctions cause improper flame characteristics and can normally be detected by watching the burner in operation. Figure 2-20 illustrates common examples of improper flame characteristics with possible causes and corrective actions.

Hard, sharp flames are caused by an excess of primary air. The flames are noisy and may produce undesirable temperatures.

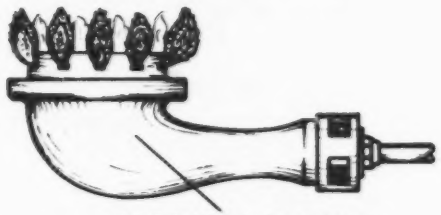
Lifting, blowing flames result from excessive port loading, excessive primary air, or excessive gas pressure. The flames are noisy and move around continuously. Carbon monoxide and aldehydes may be formed, and the burner will operate inefficiently because combustion is not complete. Very shallow burner ports tend to increase lifting flame problems.

Small flames are normally due to insufficient gas supply or undersized orifices. Combustion may be complete but the appliance does not operate at its rated Btu capacity.

A *yellow flame* or yellow tipping of a blue flame is normally caused by an insufficient primary air supply. The yellow color is caused by glowing carbon particles produced by incomplete combustion. Carbon monoxide and soot will be formed if the main burner flame comes in contact with a cool surface. Dust particles in the air may glow as they pass through the

FIG. 2-19

PROPER BURNER FLAME



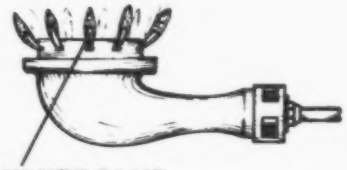
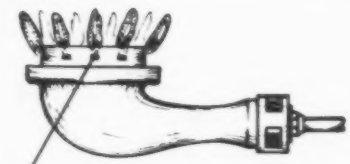
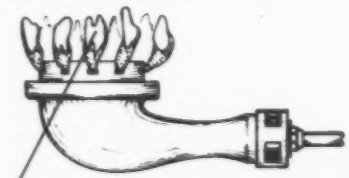
CAST-IRON BURNER

CHARACTERISTICS
1. BLUE COLOR
2. FLAME SEATED ON BURNER PORT
3. WELL DEFINED

BEST DOCUMENT AVAILABLE

FIG. 2-20

IMPROPER MAIN BURNER FLAMES

BURNER	TYPE	POSSIBLE CAUSES:	CORRECTIVE ACTIONS:
 WHITE-BLUE	HARD, SHARP FLAME	1. Excess of primary air.	1. Adjust primary air shutter.
 DEAD SPACE	LIFTING, BLOWING FLAME	1. Excessive port loading. 2. Excessive primary air. 3. Excessively high gas pressure.	1. Check orifice alignment. Also check and clean all ports. 2. Check and adjust air shutter. 3. Adjust gas pressure. (use Manometer).
BLUE	SMALL FLAME	1. Clogged burner orifice. 2. Clogged venturi. 3. Restricted or clogged gas supply line. 4. Excessively low gas pressure.	1. Clean burner orifice. Replace, if necessary. 2. Clean venturi. Replace burner if necessary. 3. Remove & clean gas supply line. Replace, if necessary. 4. Adjust gas pressure. (Use Manometer).
 YELLOW	YELLOW FLAME	1. Insufficient primary air supply. 2. Blocked primary air shutter. 3. Oversized burner orifice.	1. Adjust primary air shutter. 2. Clean primary air shutter. Adjust shutter for proper air-gas mixture. 3. Replace burner orifice. (Use orifice guides).

BEST DOCUMENT AVAILABLE

flames, causing orange-yellow streaks to appear in the flames. These color streaks have little or no effect on burner operation and should not be confused with true yellow-tipping.

Floating flames are caused by a lack of combustion air. This is usually caused by a blocked flue passage in the heat exchanger or by a blocked vent. The flames are lazy-looking. They do not have well-defined cones and appear to be "reaching" for air. They are long, ill-defined, quiet flames which roll around, sometimes completely off the burner ports. The flames are hazy blue with some yellow flame or yellow-tipping. Usually a strong aldehyde odor is present. Due to this malfunction, combustion products may smother the pilot flame.

Flame rollout is a special case of floating flames which occurs when the flames "reach out" for air through the secondary air opening when the main burner is ignited. Flame rollout may create a fire hazard, scorch appliance finish, burn wires, and damage controls. It is usually caused by lack of draft over the burners.

Flashback is a burner malfunction which may or may not be detectable by visual observation. When flashback occurs in a burner, the air-gas mixture ignites inside the burner and burns near the orifice. The flame will produce a roaring noise like a blowtorch. Combustion will be incomplete and carbon monoxide, aldehydes, and soot may be formed. Prolonged operation in a flashback condition can cause damage to the burner. Flashback normally results from an excess of primary air, insufficient flow of gas, or both. Proper adjustment of the primary air or gas supply will usually correct flashback malfunctions.

Extinction pop is a special case of flashback which occurs when the burner is shut off. Extinction pop, as the name implies, creates a noise or "bang". Reducing primary air, if possible, may eliminate it. Otherwise, it may help to slightly increase gas pressure and decrease gas orifice size. The changes provide a faster flow of the final air-gas mixture and allow the air shutter to be set in a more closed position. Gas valves which do not completely seat or close may also cause this popping noise.

MEASURING INPUT RATINGS

Heating appliances produce heat most efficiently when operated at their design capacity. In order to determine whether an appliance is operating at designed capacity, the actual fuel consumption must be measured and compared with the design capacity of the appliance. The *input rating* of a heating appliance is its maximum gas-burning capacity and is normally expressed in "Btu's per hour" and is stamped into the appliance name plate. For a specific gas, this rating can be converted to a flow rate expressed in "cubic feet per hour". Gas supply pressure and orifice size are selected by the appliance manufacturer to produce this flow rate of fuel gas. The input rating is based on the heating value of the fuel gas supplied and does not represent the total amount of usable heat which the appliance can deliver.

The *input rate* is the quantity of fuel or heat potential actually supplied to an appliance, expressed in volume or heat units per unit of time, such as cubic feet per hour or Btu's per hour. Input rating is the gas-burning capacity of an appliance, or the actual amount of gas used. The input rate of an appliance can be checked by clocking the gas meter, or by measuring the gas supply pressure, and determining the orifice size by using the orifice guides.

Determining Input Rates by Meter Clocking

Where practical, gas input rates of appliances should be checked by metering gas flow. To obtain an accurate check for one appliance, all other gas appliances and pilots served by the meter should be turned-off. If it is impractical to extinguish all the pilots on other appliances, input rate of the burner can be measured as the difference in total gas flow when a particular appliance is turned on and turned off.

Figure 2-21 shows a typical domestic gas meter index with half-foot and two-foot test dials. The total gas flow is determined by timing one complete revolution of the test dial and using that time in the following equation:

$$\text{Cubic Feet per Hour} = \frac{(\text{Test Dial Size}) \times 3600}{\text{Seconds for One Revolution}}$$

For example, the gas flow through a meter with a two-foot test dial which requires 60 seconds to make one revolution would be:

$$\frac{2 \times 3600}{60} = 120 \text{ Cubic Feet per Hour}$$

Tables have been prepared which give gas input rates for various meter sizes. Figure 2-22 shows one such table. Input rate can be converted to Btu/hr. by multiplying the tabulated cubic ft/hr. value by the heating value of the fuel gas. Again, it should be noted that the heating value of one cubic foot of natural gas may vary from 900-1200 Btu's depending on the particular gas supplier. Check with local supplier for heating value of the gas.

Determining Input Rates By Orifice Size And Gas Pressure

If meter clocking is not practical, the input rate can be determined by measuring gas supply pressure at the manifold, determining orifice size, and

BEST DOCUMENT AVAILABLE

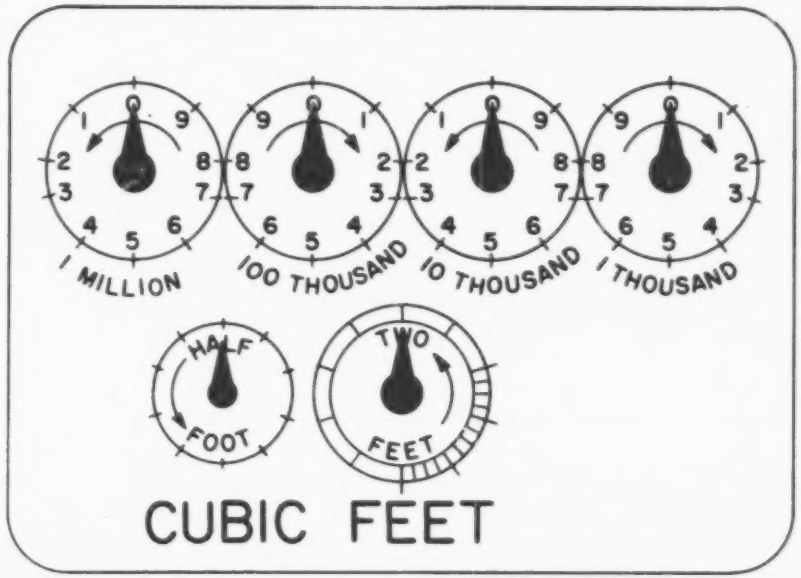
using the orifice guides to find input rate. Gas supply pressure can be measured using a low pressure test gauge or manometer and the procedures outlined in Section 1 of this manual. If the orifice size is not recorded on the appliance name plate or identifying tag, then the orifice should be removed, cleaned, and its size determined. This can be accomplished by using the shanks of standard twist drills, being careful not to damage or enlarge the orifice. With gas supply pressure and orifice size, the input rate can be determined directly from the orifice guides.

Adjusting Input Rate

If the measured input rate of the appliance is not equal to the designed input rating, the gas supply pressure should be adjusted and/or the orifice size changed. Orifice sizes for various supply pressures and input rates can be determined by referring to the orifice guides in Figures 1-17, 1-18, and 1-19, and the procedures outlined under "Orifices" in Section 1 of this manual.

FIG. 2-21

DOMESTIC GAS METER INDEX



BEST DOCUMENT AVAILABLE

FIG. 2-22

GAS INPUT TO BURNER IN CUBIC FEET PER HOUR

Gas Input to Burner in Cubic Feet Per Hour

Seconds for One Revolution	Cubic Feet Per Hour			
	Size of Test Meter Dial			
	One-Half Cu.Ft.	One Cu.Ft.	Two Cu.Ft.	Five Cu.Ft.
10	180	360	720	1,800
11	164	327	655	1,636
12	150	300	600	1,500
13	138	277	555	1,385
14	129	257	514	1,286
15	120	240	480	1,200
16	112	225	450	1,125
17	106	212	424	1,059
18	100	200	400	1,000
19	95	189	379	947
20	90	180	360	900
21	86	171	343	857
22	82	164	327	818
23	78	157	313	783
24	75	150	300	750
25	72	144	288	720
26	69	138	277	692
27	67	133	267	667
28	64	129	257	643
29	62	124	248	621
30	60	120	240	600
31	58	116	232	581
32	56	113	225	563
33	55	109	218	545
34	53	106	212	529
35	51	103	206	514
36	50	100	200	500
37	49	97	195	486
38	47	95	189	474
39	46	92	185	462
40	45	90	180	450
41	44	88	176	440
42	43	86	172	430
43	42	84	167	420
44	41	82	164	410
45	40	80	160	400
46	39	78	157	391
47	38	77	153	383
48	37	75	150	375
49	37	73	147	367
50	36	72	144	360
51	35	71	141	353
52	35	69	138	346
53	34	68	136	340
54	33	67	133	333
55	33	65	131	327

Seconds for One Revolution	Cubic Feet Per Hour			
	Size of Test Meter Dial			
	One-Half Cu.Ft.	One Cu.Ft.	Two Cu.Ft.	Five Cu.Ft.
56	32	64	129	321
57	32	63	126	316
58	31	62	124	310
59	30	61	122	305
60	30	60	120	300
62	29	58	116	290
64	29	56	112	281
66	29	54	109	273
68	28	53	106	265
70	26	51	103	257
72	25	50	100	250
74	24	48	97	243
76	24	47	95	237
78	23	46	92	231
80	22	45	90	225
82	22	44	88	220
84	21	43	86	214
86	21	42	84	209
88	20	41	82	205
90	20	40	80	200
94	19	38	76	192
98	18	37	74	184
100	18	36	72	180
104	17	35	69	173
108	17	33	67	167
112	16	32	64	161
116	15	31	62	155
120	15	30	60	150
130	14	28	55	138
140	13	26	51	129
150	12	24	48	120
160	11	22	45	112
170	11	21	42	106
180	10	20	40	100
190	9.5	19	38	95
200	9	18	36	90
210	8.5	17	34	86
220	8	16	33	82

BEST DOCUMENT AVAILABLE

SECTION 3

HEAT TRANSFER AND VENTING FUNDAMENTALS

CHARACTERISTICS OF HEAT TRANSFER

The primary purpose of space heating appliances is to heat the living space within dwellings. Different types of these appliances accomplish this in various ways. In *warm air* heating, air flows over the appliance heat exchanger, where it is heated, and then distributed into the dwelling by natural or forced circulation. *Hydronic* systems utilize appliances which produce hot water or steam. The heated fluid or vapor is then piped to radiators or coils located in the living space. The radiators then transfer the heat to the surrounding air.

Types of Heat Transfer

The transfer of heat can occur in three different ways: by convection, by conduction, and by radiation. All three heat transfer mediums occur to some degree in all heating appliances.

Convection is the movement of heat, from one area to another, which results from the movement of the substance containing the heat. The heat, in effect, rides "piggyback" on the heated substance. Heat transfer by convection occurs only when there is physical movement of a heated substance (i.e., air). Warm air is lighter than cold air and tends to rise, carrying heat along as it rises. This is a very simple form of *convective* heat transfer. Floor heaters rely heavily on air currents to transfer heat throughout the dwelling. Air, heated within these appliances rises, by natural convection and displaces the cooler air in the room. The cooler air then settles to the floor and is reheated.

Conduction is the transfer of heat *through* a substance *or* from one substance to an adjacent substance. This heat transfer takes place without the substance itself moving. If one end of a metal rod is placed in a flame, the rod will *conduct* heat away from the flame even though the rod itself does not move. Heat will move from the hot end of the rod to the cooler end raising the temperature throughout the entire length of the rod. In some heating appliances, heat is transferred by conduction through metal barriers (heat exchangers) to air or water on the other side of the combustion zone.

Radiation is a form of heat transfer in which heat passes through less dense substances, such as air, without noticeably warming them, while warming solid objects in its path. On a cold day, sunshine on a closed automobile will warm it, even though the air, through which the *radiant* energy of the sun is passing, is extremely cold. Radiant heat is much like light in that it passes through air without affecting it, but is stopped completely by solid objects.

A fireplace heats a dwelling primarily by radiation. Objects closest to the fireplace are heated most intensely. Objects farther away receive less radiation and those in the "shadow" receive none. They may remain relatively cool even though close to the fireplace.

Transfer of heat by radiation occurs to some extent in all heating appliances, but *radiant* appliances rely almost exclusively on radiation to transfer heat produced in the appliance to the dwelling.

WARM AIR HEATING — HEAT EXCHANGERS

Heat exchangers in warm air heating appliances have an inner combustion chamber in which the burner operates to produce heat, and an outer chamber through which air passes to be heated. The heat exchanger separates these two areas and ensures that products of combustion are not mixed with the warm air supply to the dwelling. A typical warm air heat exchanger is shown in Figure 3-1.

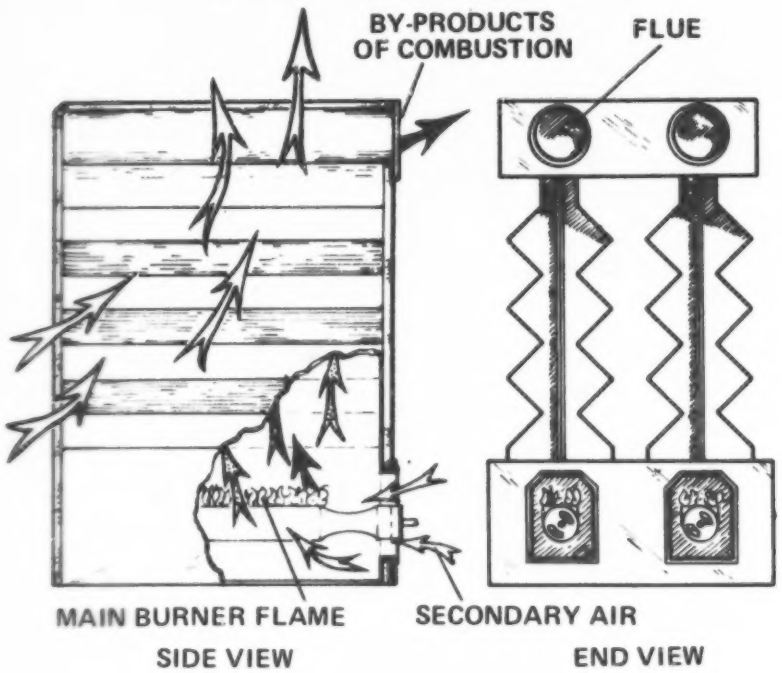
Heat exchangers are manufactured in a variety of shapes and sizes and are constructed of several types of materals. As a general rule, all exchangers in heating appliances are constructed of metal. The metals most commonly used are cold-rolled steel or an aluminized steel material. Metal is quite durable and transfers heat well; however, untreated metals easily rust or corrode. Today, most manufacturers coat heat exchangers with a special ceramic material to resist corrosion.

The heat exchangers in gas furnaces and other heaters are often called "clamshells". The name "clamshell" evolved because heat exchangers are often made by stamping one left and one right side. The light gauge metal

BEST DOCUMENT AVAILABLE

FIG. 3-1

TYPICAL HEAT EXCHANGER



shells are then welded together along a common vertical seam to form a clamshell design.

Heat exchanger design must comply with five important design requirements:

1. The heat exchanger must provide an adequate space for both the main burner and combustion without flame impingement.
2. The heat exchanger must provide an internal surface design which allows an even distribution of heat.
3. The heat exchanger interior must provide an adequate updraft for the heated products of combustion to draw sufficient *secondary air* into the combustion chamber.
4. The heat exchanger must provide adequate heat transfer for the requirements of the particular appliance.
5. The heat exchanger must provide an adequate outlet for the products of combustion.

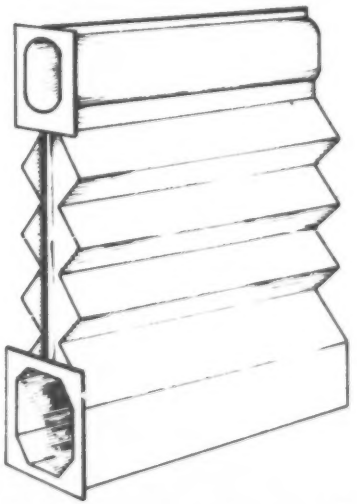
The structure of the heat exchanger varies according to the particular application and manufacturer's design. Some heat exchangers utilize zigzag passageways in order to increase the turbulence of the combustion gases and evenly distribute the heat within the exchanger (see Fig. 3-2). Other heat exchangers utilize a tapered exchanger body to increase the speed of the rising heated air and improve heat transfer (Figure 3-3). Still others utilize a "ribbon design" to achieve this function. In many heat exchangers, engineers have designed indentations or dimples in the walls which reduce the cracking and popping noises created by the exchanger during expansion (heating) and contraction (cooling).

At the outlet of the heat exchanger is the appliance draft diverter and vent connector which directs the products of combustion from the heat exchanger *flue opening*, into the vent.

Cool air from the return air duct passes over the outside of the heat exchanger walls and is discharged into the supply ducts as warm air. Older gravity systems rely on the natural tendency of warm air to rise (convection) to create movement of air over the heat exchanger. Modern forced-air systems are equipped with a blower to force air over the heat exchanger walls and throughout the living space.

FIG. 3-2

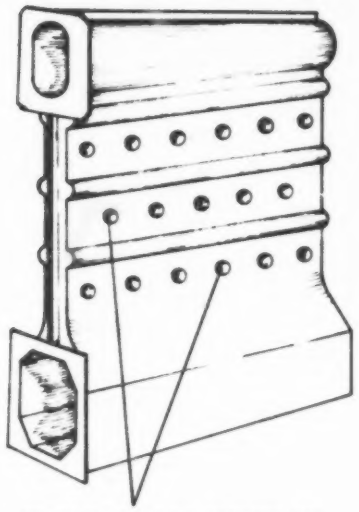
ZIG ZAG HEAT EXCHANGER



BEST DOCUMENT AVAILABLE

FIG. 3-3

TAPERED HEAT EXCHANGER



STRUCTURAL DIMPLES

Heat generated by combustion at the main burner is transferred to the walls of the heat exchanger. The heat transfer is fairly uniform due to special design features. Restrictor plates or baffles are located at the outlet of the heat exchanger. The baffles actually slow down the combustion gases which allows for greater heat transfer.

The heat exchanger is designed so the air passing over its outside will pick up the maximum amount of heat energy available from the entire exchanger surface. If the heat transfer is not uniform over the entire exchanger surface, "HOTSPOTS" (areas of excessively high temperatures) can damage or burn through the metal heat exchanger wall.

Malfunctions

Since the heat exchanger has no moving parts, it can only develop a few problems. The heat exchanger is normally constructed of light gauge metal; therefore, one malfunction which may occur is deterioration of the exchanger wall. This breakdown may simply be due to expansion and contraction over years of use. While, most heat exchangers are coated with a protective ceramic layer, age may cause the coating to break down. This is especially true in the area of a seam. With the absence of the protective ceramic coating, the metal body of the exchanger is exposed to the elements and will rust or corrode.

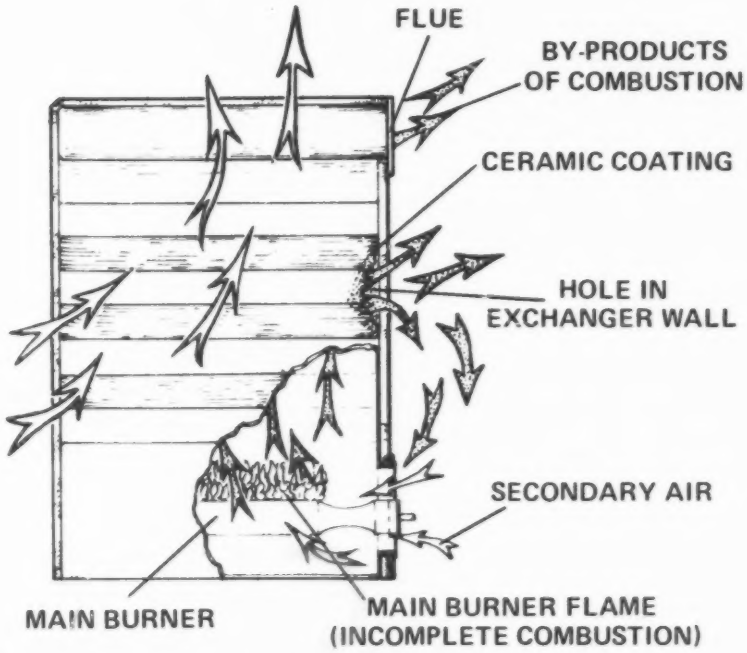
Heat exchanger failure is often caused by leaking humidifiers, poorly designed gas vents, chemicals in the air, and control components which malfunction.

When the exchanger wall develops a hole, the condition becomes quite hazardous to occupants of the dwelling. For example, the heat exchanger in Figure 3-4 has developed an opening near the welded seam on the side of the unit. Most products of combustion exit the flue as intended; however, some of the gases may exit the hole in the exchanger wall and leak into the conditioned air supply to the dwelling. In addition to creating a potential health hazard, a leaking heat exchanger can cause the main burners to operate improperly. Heat exchanger leaks must be promptly corrected. This typically involves replacing the exchanger or the entire heating appliance.

When burners are properly adjusted, the products of combustion are relatively harmless since they are made up primarily of water vapor, and carbon dioxide (CO_2). However, when the main burner is improperly adjusted and combustion is incomplete, the products may include carbon

FIG. 3-4

FAULTY HEAT EXCHANGER



BEST DOCUMENT AVAILABLE

monoxide, aldehydes, and soot. Although the other products of incomplete combustion can be harmful and damaging, carbon monoxide (CO) is the primary health hazard. A serious health hazard may develop if even small concentrations of CO accumulate in the conditioned air. Unless the dwelling has an abundant supply of fresh air ventilation, asphyxiation (death due to lack of oxygen) or actual CO poisoning (death due to contamination of blood) may occur.

There are several different methods of detecting leaks in heat exchangers of warm air heating appliances. However, the *only certain method to detect a leak is to dismantle the appliance and visually inspect the heat exchanger.*

Because of the potential liability to the servicing organization, the previously mentioned method is recommended in detecting heat exchanger leaks. Because of the time required and the expense to the consumer, other less reliable methods of leak detection have been used.

The most practical alternative method of testing for heat exchanger leaks is to measure CO and CO_2 levels. If the appliance seems to be operating properly and these levels are *other* than normal, a leaking heat exchanger may be the cause. In this type of test, a small sample of combustion gas is extracted from the appliance and analyzed for percentage of CO and CO_2. The actual procedure for this test is discussed later in this section.

Visual inspection of the main burner flame characteristics may also indicate faulty heat exchangers. Normally, this procedure is only applicable to appliances which use a blower to distribute heat (forced air heating systems). If the main burner flame has normal characteristics with the blower "off" but, with the blower "on", tends to lift from the burner ports, the heat exchanger is probably faulty.

Smoke bombs have also been used with limited success in testing for leaking heat exchangers. Basically, the smoke bomb is inserted into the heat exchanger cavity. If smoke is detected in the supply air to the dwelling, the exchanger is leaking. In many cases, however, the smoke drifts out of the exchanger and into the supply air even if the exchanger is not leaking. This is normally caused by a smoke bomb which develops more smoke than the system can adequately vent.

An additional procedure developed to determine heat exchanger leaks is called the "Salt Test". Basically, a solution of sodium carbonate (soda ash) and water are mixed and sprayed into the heat exchanger while the burners are operating with the blower off. A propane torch is then carefully inserted into the plenum or supply air registers. If the typical blue propane flame of the torch turns yellow, it indicates a leak in the heat exchanger. The chemical reaction between the sodium carbonate vapor and the burner flame creates a change in color. Although this test is performed by certain service agencies, it may not be the most practical or effective means to detect leaks in exchangers.

The last popular method of testing is called the "odor test". Basically, a small quantity of wintergreen, liquid peppermint, or other aromatic substance is deposited in a small metal container (bottle cap). The cap and substance are then placed on each main burner. As the substance is heated, it generates a distinctive odor. If the odor is detected in the supply air of the dwelling, a leak exists. This method of testing has also met with only limited success.

Despite all the alternatives given, the *only* reliable method to ensure that a heat exchanger is not leaking is to visually inspect it.

HYDRONIC HEATING - HEAT EXCHANGERS

Heating systems which rely on water or steam to transfer heat into the dwelling are called *hydronic* heating systems. Because of the high heat-carrying ability of water, heat exchangers of hydronic systems are relatively small compared to those used in warm air furnace systems.

Two kinds of hot water systems are in use: gravity systems, more common in older installations, and forced systems, more common in modern installations. Gravity systems rely on the difference in density between cool and hot water to circulate the water. These systems have no circulating pump, but require large pipes for circulation. Gravity systems also have larger radiators and contain greater amounts of water. Because of the large amount of water which must be heated, these systems are slower to respond to a demand for heat. Similarly, gravity systems are slow to stop heating the dwelling once the desired temperature has been reached (may "overshoot" the selected temperature).

Forced hot water systems use a pump to circulate water through distribution pipes to radiators throughout the dwelling. A typical domestic hot water boiler is shown in Figure 3-5. The burner arrangement and combustion chamber is similar to that used in warm air furnaces.

The two basic types of heat exchangers used in hot water boilers are the *fire tube* and *water tube*. Basically, fire tube boilers heat water flowing over the outside surface area of the exchanger. Water tube boilers heat water flowing through the inside surface area.

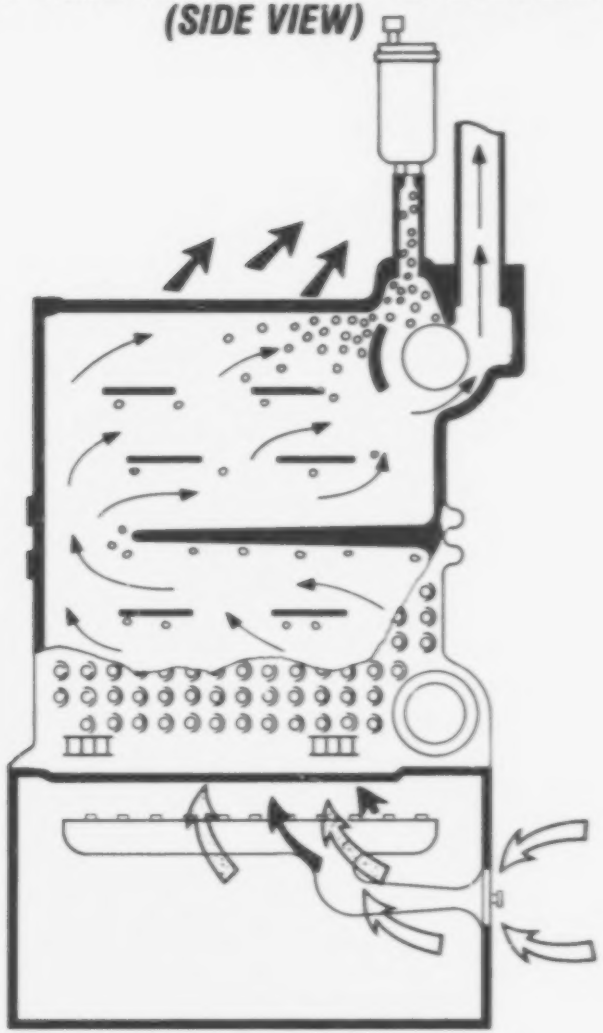
The boiler shown in Figure 3-5 uses heat exchangers which function basically in the same way as warm air heat exchangers. However, water, not air, circulates around the heat exchanger to absorb heat. Heat produced in the combustion chamber is transferred by conduction through the cast-iron wall of the heat exchanger, heating the water on the other side. The vertical combustion chamber passages are usually studded with tips. These tips create turbulence in the combustion gases and also provide an increased surface area to improve heat transfer. Baffles are normally cast in the water passages to create mixing. In addition, the baffles regulate the flow of water through the heat exchanger. Cast-iron boilers

BEST DOCUMENT AVAILABLE

FIG. 3-5

CAST IRON HEAT EXCHANGER

(SIDE VIEW)



BEST DOCUMENT AVAILABLE

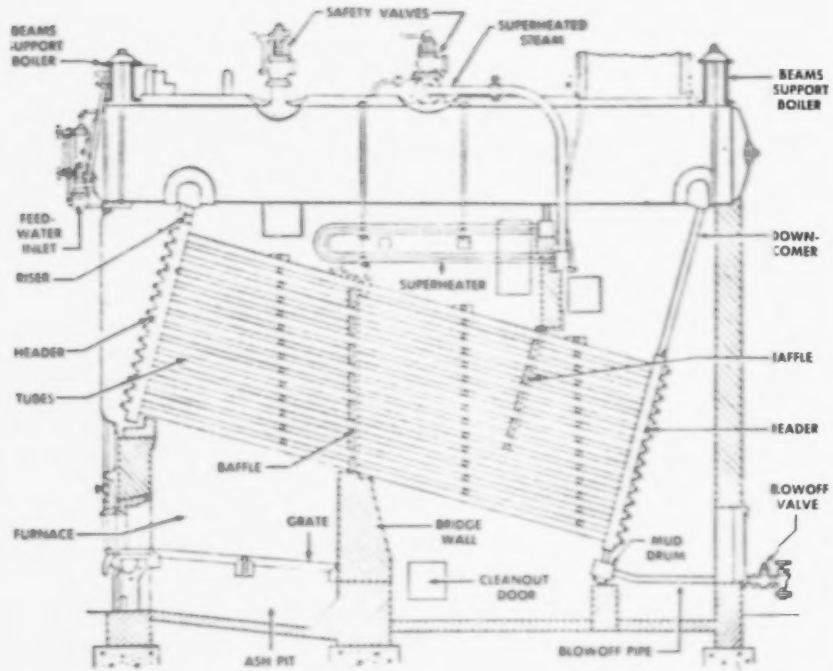
are normally constructed from several heat exchanger sections bolted together to form a common water passageway or individually connected to an external pipe header. Corrosion, both on the water side, and on the combustion chamber side where condensation can occur, can be a problem in hot water boilers. Cast-iron is often used because of its relatively high resistance to corrosion.

Water tube exchangers typically have a single combustion chamber with a noncombustible lining and multiple tubes as shown in Figure 3-6. Heat produced in the combustion chamber is transferred through the walls of the heat exchanger coils or tubes and into the water. The water gets good exposure to the combustion heat because the exchanger tubes provide a large surface area. This results in highly efficient heat transfer.

Hot water boilers are utilized in one of two basic ways to provide heat for a dwelling. In "Direct Heat" systems, the water circulated around the tube or coil-type heat exchanger is piped directly to radiators throughout the dwelling.

FIG. 3-6

WATER-TUBE BOILER



"Indirect Heat" systems are completely closed systems. The primary water circulates internally in the boiler. This primary water serves as a medium of heat transfer from the primary heat exchanger in the combustion chamber to a secondary heat exchanger (indirect heating coils). Because the primary water circulates only within the boiler, scale and corrosion in the high temperature areas immediately surrounding the combustion chamber can be more easily controlled. Water circulated through the dwelling is heated in the indirect heating coils at a lower temperature where scale and corrosion problems are less troublesome.

Malfunctions

Leaks in hydronic system heat exchangers may be very difficult to detect. This is because small water leaks around the heat exchangers tend to immediately vaporize on hot surfaces and go unnoticed. When the boiler is off, the serviceman should note any signs of leakage (i.e., excessive rust, water puddles, white water film). If a leak exists, gaskets and/or heat exchangers should be repaired before the appliance is placed back in operation.

Radiators

Radiators used in hot water heating systems function as secondary heat exchangers, transferring heat into the dwelling from the circulating water. Radiators designed for use in hot water systems require a supply and return line since water is normally circulated through the system by either gravity or by a circulating pump.

FIG. 3-7A

FINNED — TUBE RADIATOR

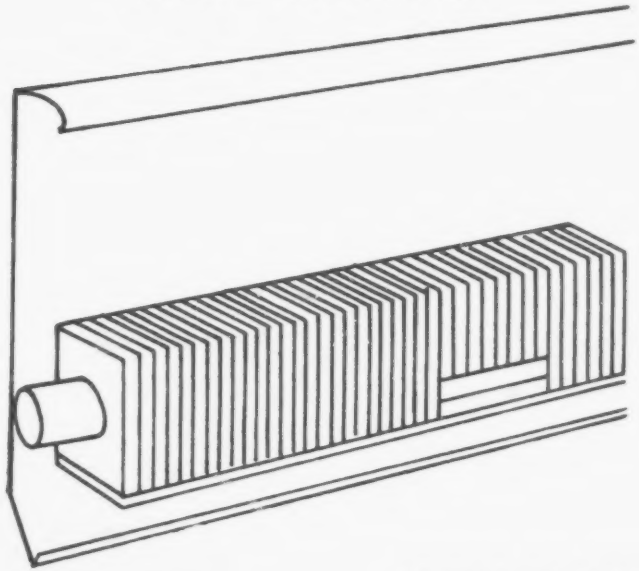
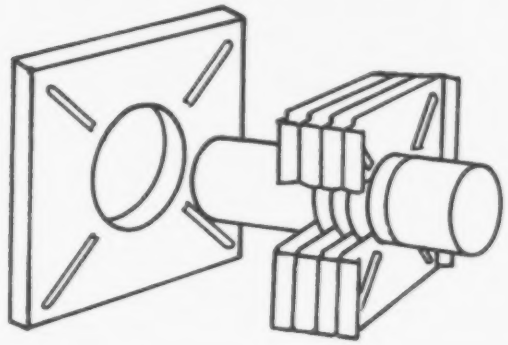


FIG. 3-7B

RADIATOR HEATING ELEMENT

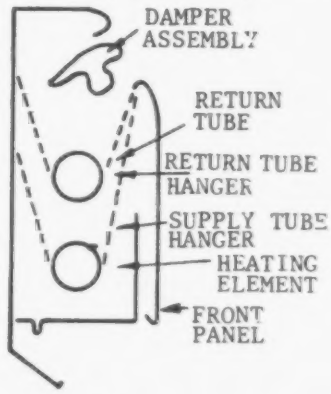


Modern radiators are normally constructed of finned-tube (convectors) or cast iron and are designed to be installed along the baseboard, particularly on the exterior walls of the dwelling. Typical finned-tube radiators (see Figure 3-7 a,b,c) are constructed of copper tubing with aluminum fins or of steel tubing with steel fins. Fins are bonded to the tube to increase heat transfer efficiency from the heating medium to the surrounding air. As the warm air rises, a convective air current is created which continually circulates cool air from the floor of the dwelling and over the outer surface

FIG. 3-7C

FINNED — TUBE RADIATOR

(END VIEW)

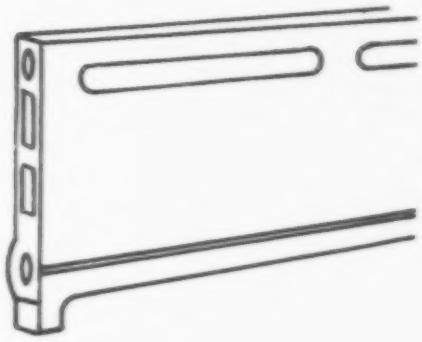


BEST DOCUMENT AVAILABLE

of the radiator. Finned-tube radiators are normally housed in a louvered sheet metal enclosure which may include dampers to control the flow of air.

A typical cast-iron baseboard radiator is shown in Figure 3-8 a,b,c,d. Cast-iron radiators are true *radiators* in that they rely primarily on *radiation* as a means of transferring heat into the dwelling. In addition, a finned surface is normally manufactured into the unit to heat the surrounding air and create upward air currents on the exterior walls of the dwelling. Because radiation accounts for a large portion of the heat transfer, cast-iron radiators must be fully exposed to be effective.

FIG. 3-8A



CAST-IRON BASEBOARD RADIATOR

FIG. 3-8B

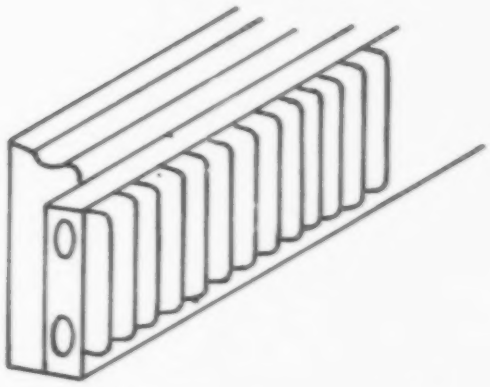
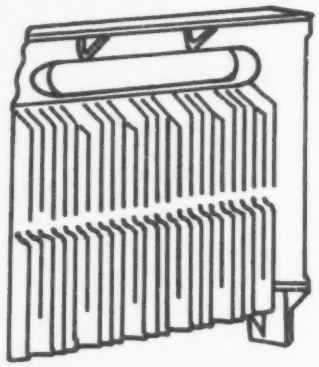
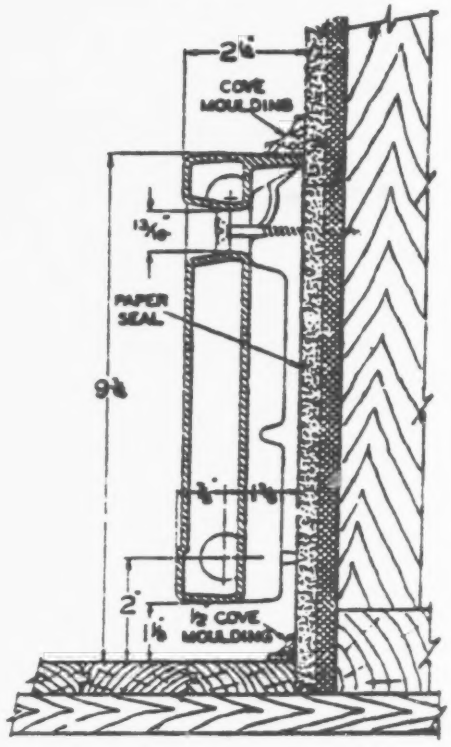


FIG. 3-8C



CAST-IRON BASEBOARD RADIATORS

FIG. 3-8D



BEST DOCUMENT AVAILABLE

The most significant common problem experienced with hydronic heating systems is scale formation and corrosion. Deposits of scale and rust decrease and/or obstruct the flow, as well as reduce the system's heat transfer capabilities.

VENTILATION

An adequate supply of air is essential for the safe and efficient operation of heating appliances. The purpose of appliance ventilation is to provide this air. The amount of air required depends on the fuel gas combustion ratio and the appliance input rating. Natural gas, for example, has a combustion ratio of 10 cu. ft. air to 1 cu. ft. gas. Ideally, for each cubic foot of natural gas burned by an appliance, 10 cu. ft. of air will be consumed and 11 cu. ft. of combustion products will be produced. As a practical matter, *excess air* is supplied to ensure adequate oxygen and complete combustion; thus more flue gases will be produced than indicated in the preceding ratio. A more complete discussion of combustion, products of combustion, and air requirements can be found in Section 2 of this manual.

In order to maintain safe conditions inside a dwelling where vented gas appliances are operating, the products of combustion must be exhausted and the air supply replenished continually. If the air supply is not adequate, combustion will be incomplete; appliance efficiency will decrease and harmful combustion gases will be generated.

The combustion process uses oxygen in the air and produces carbon dioxide and water vapor. When products of combustion are not removed and fresh air supplied, the oxygen supply is depleted. The combustion process, deprived of sufficient oxygen, becomes incomplete and harmful. Under these conditions products such as carbon monoxide may be formed. Even water vapor, normally a harmless product of combustion, can increase the humidity in the dwelling and cause problems by condensing on cool surfaces. This condensed water can rot wood, discolor fabrics, harm wall coverings, and corrode metal.

In some instances, combustion air is supplied by infiltration through cracks around doors and windows. In newer homes which are more tightly constructed, it is necesssary to provide special means for supplying air to the appliances, such as ducts or louvered grills communicating with the outdoors.

The operation of exhaust fans, kitchen ventilation systems, clothes dryers, or fireplaces may create unusual requirements for ventilation. The are needed to meet these requirements should not be drawn from the same interior source as combustion air for an appliance. Also, air returning to a forced-air furnace after circulating through the house should be isolated from the combustion air space and interior air supply.

The National Fuel Gas Code (NFPA #54, ANSI Z223.1) outlines requirements for the installation of appliances and related ventilation and venting systems. The provisions of NFPA #54 have gained wide acceptance as the basis for local building codes and are the source for the sizing and location recommendations which follow. However, state and local codes should also be consulted before installing an appliance or modifying any vent or ventilation system.

Ventilation for Appliances Located in Unconfined Spaces

Unconfined spaces will normally have enough natural flow of outside air to meet most requirements for ventilation. If the construction is unusually tight, air from outdoors will be needed. This can be accomplished by providing a permanent opening or openings with a total free area of not less than one square inch per 5,000 Btu/hr of total input to appliances. For example, an appliance with an input rating of $\frac{100{,}000}{5{,}000}$ Btu/hr would require 20 square inches of free area.

If ducts are used, they must have the same cross-sectional area as the free area of the openings to which they connect. The minimum dimensions of rectangular air ducts (small side) shall not be less than 3 inches. Screening to cover the openings to the outside should not be smaller than ¼ inch mesh and shall not be capable of closure. Insect screening and louvers reduce effective area so when used, openings must be oversized to compensate.

Air for Combustion and Ventilation for Appliances Located in Confined Spaces

A room in which appliances are installed must be considered as confined space, regardless of size, if a source of air supply is not directly available. If ventilation air is to be provided from inside the building, two permanent openings must be provided as shown in Figure 3-9. The openings must be made into areas of the building which have adequate infiltration from outdoors. One opening should be located within 12 inches of the bottom and the other within 12 inches of the top of the enclosure. Each opening shall have a free area of not less than one square inch per 1,000 Btu/hr of the total input ratings of all gas appliances in the enclosure.

The confined space shall have one opening which directly connects with the outdoors (i.e., ventilated crawl space or attic) to supply additional air for combustion and for venting (dilution air) if openings cannot be made into areas of the building with adequate air infiltration from outdoors. This opening shall have a minimum free area of one square inch for each 5,000 Btu/hr. A typical example of this type of installation is a warm air furnace with an input rating of 120,000 Btu/hr and a water heater with an input rating of 40,000 Btu/hr both installed in a closet or utility area. The combined input rating would be 120,000 + 40,000 or 160,000 Btu/hr.

BEST DOCUMENT AVAILABLE

Floor and ceiling vents connected to a hall or other open area would be required to have $\frac{160,000}{1,000}$ or 160 square inches free opening area. An additional opening of $\frac{160,000}{5,000}$ or 32 square inches would be required to the ventilated attic or crawl space.

Air for Combustion and Ventilation Provided from Outdoors

If all air is to be provided from outdoors then ventilation openings must be provided as shown in Figure 3-10, 3-11, or 3-12. If air openings connect directly or through vertical ducts with the outdoors or with a ventilated attic or crawl space, then the free area of the openings must not be less than one square inch per 4,000 Btu/hr of the total input ratings of all appliances in the enclosure. If ventilation is through horizontal ducts (Figure 3-12), then a free area of one square inch per 2,000 Btu/hr must be provided. For example, if the total input ratings of all appliances are $\frac{100,000}{4,000}$ Btu/hr then the free area must be 25 square inches for vertical ducts or directly connected openings. Horizontal ducted openings would require $\frac{100,000}{2,000}$ or 50 square inches.

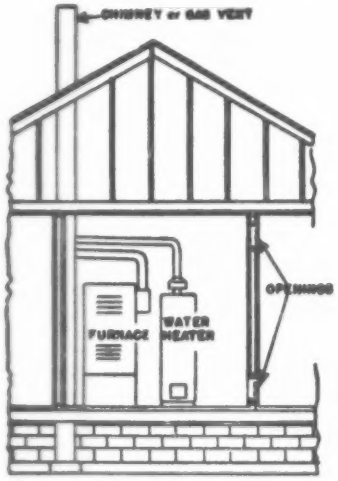
In all cases the openings must be located within 12 inches of the floor and ceiling. The cross-sectional area of ducts shall not be less than the free area requirements which they serve.

It is important to realize that metal louvers for ducts whose dimensions have the same square inch requirements as the example usually provide only 75% free area opening. Wooden louvers normally allow only 25% area opening. In determining louver size, one must consider these restrictions to free area and increase the opening accordingly.

VENTING GAS APPLIANCES

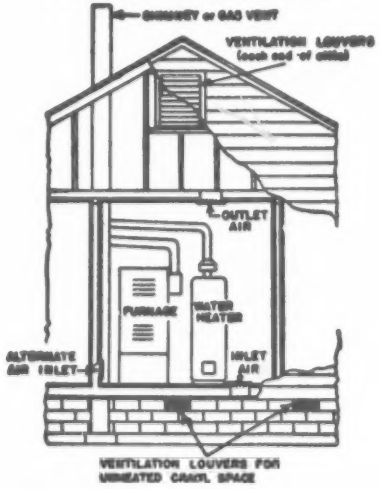
Proper venting of heating appliances safely exhausts combustion products to the outside and provides for good air circulation and an adequate oxygen supply for the appliance. Air supplied to the appliance by *ventilation* is removed from the appliance along with products of combustion by *venting*. An effective venting system ensures that all combustion products are removed and sufficient excess air is drawn through the combustion chamber to provide complete combustion of fuel gases.

FIG. 3-9
INSIDE AIR OPENINGS



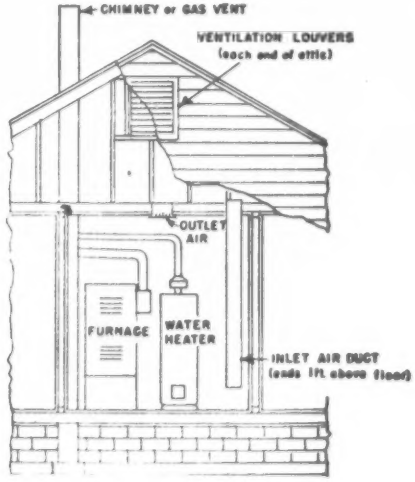
NOTE: Each opening shall have a free area of not less than one square inch per 1,000 Btu per hour of the total input rating of all appliances in the enclosure.

FIG. 3-10
OUTSIDE AIR
FROM CRAWL SPACE



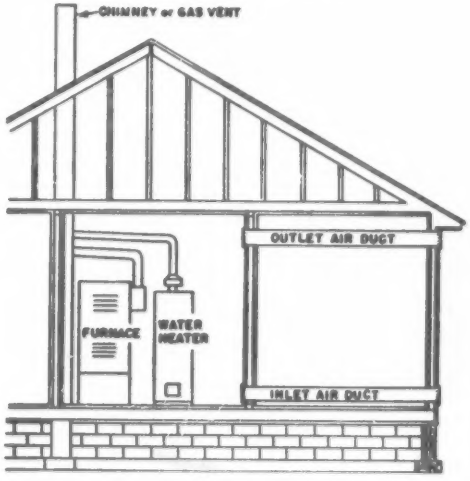
NOTE: The inlet and outlet air openings shall each have a free area of not less than one square inch per 4,000 Btu per hour of the total input rating of all appliances in the enclosure.

FIG. 3-11
OUTSIDE AIR
FROM ATTIC SPACE



NOTE: The inlet and outlet air openings shall each have a free area of not less than one square inch per 4,000 Btu per hour of the total input rating of all appliances in the enclosure.

FIG. 3-12
OUTSIDE AIR FROM
DIRECT OPENING



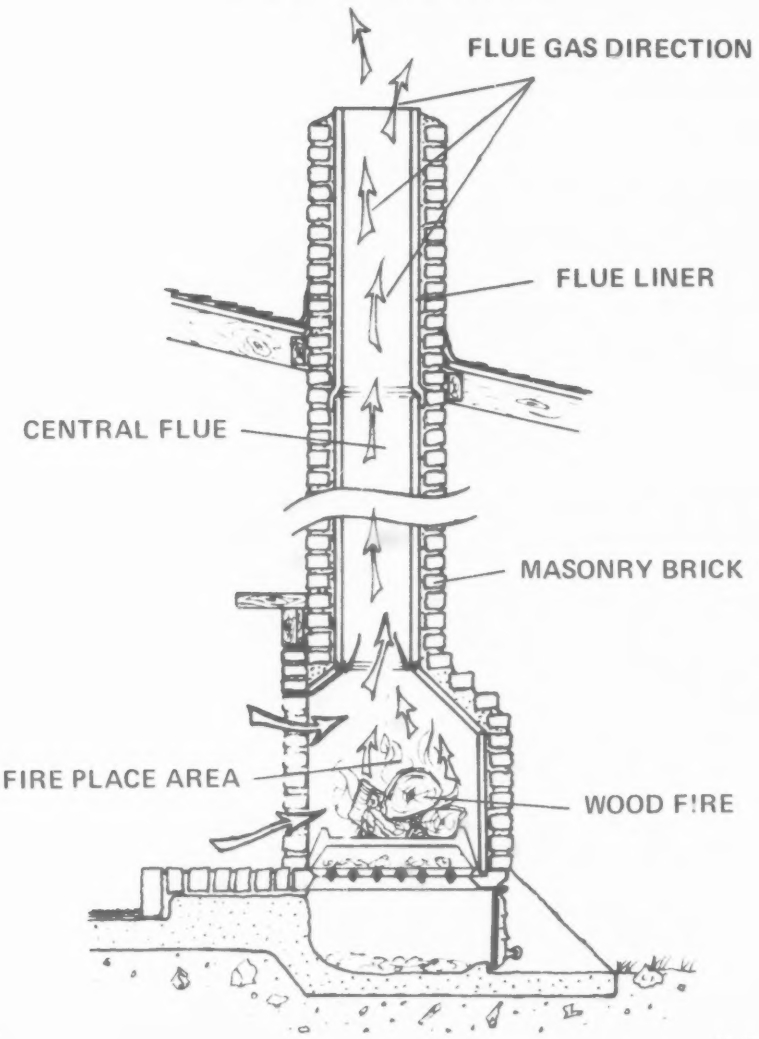
NOTE: Each air duct opening shall have a free area of not less than one square inch per 2,000 Btu per hour of the total input rating of all appliances in the enclosure.*

BEST DOCUMENT AVAILABLE

Conventional gas heating appliances use two major types of venting systems; gravity vents and special vents. Gravity venting systems operate on the principle of convection or the temperature difference between the products of combustion and the outside air. This is the most common type of venting system. Special or power vents use mechanical blowers to either draw or force the products of combustion out the vent. Special or power vents are used in very specialized systems and/or appliances and for this reason will not be detailed.

FIG. 3-13

BASIC VENTING SYSTEM



An example of a basic venting system is the masonry chimney; used in conjunction with a wood or coal burning fireplace. This basic system (see Figure 3-13) includes a combustion chamber and masonry chimney (vent). This system operates on the same concept as modern gas venting systems.

Whether it is a modern gas vent or a masonry chimney, each provide a passageway or opening between two spaces. For example, the masonry chimney in Figure 3-13 connects the inside of the building to the outdoors. Whenever the temperature or pressure inside the building is greater than outdoors, air flows through the vent and out of the building. Whenever the temperature or pressure outdoors is greater than indoors, air flows through the vent and into the building. The greater the difference in temperature or pressure, the greater the air movement.

For example, when wood is ignited in the combustion chamber, air surrounding the fuel supports the combustion. Due to the difference in temperature, the hotter and lighter flue gases rise up the chimney and into the atmosphere. This movement of flue gases creates a draft which draws room air into the combustion chamber. This continuous movement creates the motive force which allows the vent to operate.

Gas appliance vents and fireplaces operate on the same principle, however, they differ in several ways. First, gas vents are designed to operate at a maximum temperature of 550°F while chimneys may operate up to 1000°F. Due to this, the draft or motive force in gas vents are far less than in fireplaces. For this reason, gas venting systems must be designed so that they minimize the resistance to the movement of flue gases, as well as minimizing the heat transferred from the flue gases.

If the flue gases are allowed to cool, the motive force is reduced. In addition water vapor, contained within the combustion by-products, condenses onto the vent walls and often leads to vent deterioration.

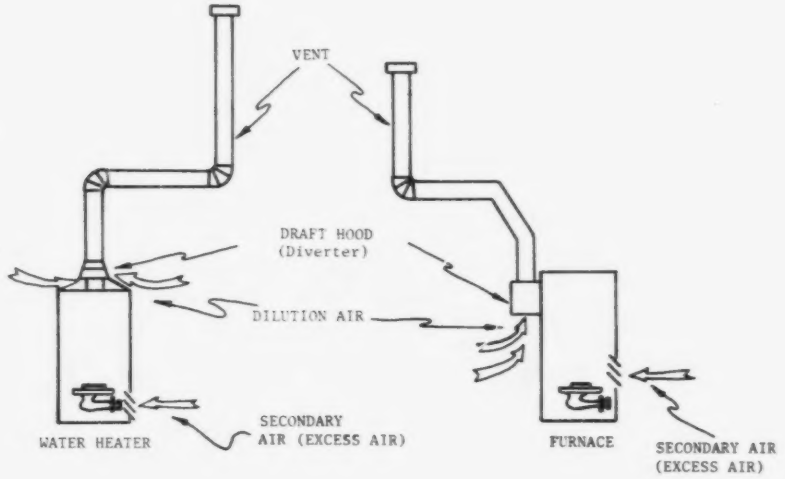
Another important difference between gas vents and fireplaces is the use of a *draft diverter* or *draft hood* (see Figure 3-14). The appliance draft diverter actually functions as a *draft regulator*. That is, the draft diverter regulates the draft up the vent by controlling the flue gas temperature.

As the flue gases exit the appliance heat exchanger through single or multiple flue openings, they enter the draft diverter. As the flue gases enter the vent, air is drawn into the draft diverter where it combines with flue gases. This air is called *dilution air*, in that it dilutes or decreases the temperature of the flue gases. The higher the flue gas temperature, the greater its velocity through the draft diverter. The greater the flue gas velocity, the greater the amount of dilution air which enters the venting system. So, the draft diverter regulates the draft up the vent by controlling the temperature of the flue gases entering the venting system. This is important because, without the use of a draft diverter, the venting system could be exposed to temperatures above its designed maximum rating.

In addition to operating as a draft regulator, the draft diverter also operates as a relief opening. That is, the draft diverter allows flue gases to exit the vent if abnormal winds produce a down draft or if the venting system above the draft diverter otherwise malfunctions.

BEST DOCUMENT AVAILABLE

FIG. 3-14
VENTING SYSTEM FOR GAS BURNING APPLIANCES



Types of Venting Systems

There are a number of types of venting systems in use today. Some have been developed for specific applications while others can be used in a variety of installations. For proper application and safe vent operation, standard vent categories have been developed with well defined performance requirements. If a manufacturer wants to certify that a particular vent design qualifies in a particular vent category, it must submit its vent to Underwriter's Laboratories, Inc. (UL). If the vent design meets the test requirements satisfactorily, the product is "listed" by UL. This listing is published so purchasers know which products have been accepted. Accepted products bear a symbol which denotes their UL listing.

Class A Chimneys

Class A chimneys are constructed of masonry, reinforced concrete or insulated metal. Masonry chimneys are the most common type in many parts of the country. Chimneys of this type were originally developed to vent the combustion gases of wood, coal, or oil burning appliances. When used for venting gas appliances, a clay tile or similar lining is preferred and is required in many building codes. While masonry and metal chimneys are constructed according to local building codes, factory-built chimneys should be UL listed.

Type B Vents

These vent pipes are constructed of noncombustible, corrosion-resistant material of sufficient thickness to provide a reasonable life. Materials used include aluminum, steel, clay tile, and asbestos-cement. All-metal types employ double wall construction enclosing an air space for insulation purposes. The vent's cross-sectional area and heat insulating quality should be sufficient to avoid excessive temperatures near adjacent *combustible materials* when installed according to specified clearances. Normally, the UL approved distance from combustibles is stamped directly on the vent. This type of vent is suitable for venting listed gas appliances with draft hoods, and is frequently used in new construction because it is less expensive to install than a masonry chimney with liner.

Type BW Vents

These vent pipes are of double wall construction (similar to Type B vents) but are oval in cross-section. They are designed specifically for installation in walls for venting listed wall furnaces, and are listed by Underwriter's Laboratories for that purpose only. BW vent installation requirements include use of additional components for *spacing*, *fire stopping*, and *flue collar* or *header* plate attachment and must be used.

Type L Vents

Type L vent construction is similar to Type B vent pipe except materials used are more heat and corrosion resistant. Other parts in contact with flue gases are constructed of the same materials and may also include aluminum coated steel. Type L venting systems are used in three cases: with gas and oil appliances listed for use with this type vent, where Type B gas vents are permitted, and for chimney and *vent connectors*. Type L venting systems are listed by UL. They are not commonly used, usually being selected for special gas applications where higher vent temperatures present a problem.

Single Wall Vents

Single wall vent pipe should be constructed of at least 20 gauge galvanized (0.0359 in.) sheet steel or at least 24 B&S gauge sheet copper or other noncombustible corrosion-resistant material. Single wall vents previously were designated as Type C gas vents. The Type C classification was recently dropped from the National Fuel Gas Codes (NFPA #54). This type of vent should only be used for runs as a connector within the space in which the appliance is located, directly through the roof or exterior wall to the outside air. It must not be installed through any concealed portion of the building structure. It is installed with specified minimum distances from combustible materials which are considerably greater than clearances for Type B or BW. In many areas, state and local codes *do not allow*

BEST DOCUMENT AVAILABLE

the use of single wall vents. Uninsulated single wall pipe is not recommended in cold climates as an outside vent for appliances equipped with draft hoods. If used in this circumstance, temperature change may cause condensation and corrosion of the vent or heating appliance. When local experience indicates condensation may be a problem, provisions should be made to drain off the condensate.

• VENTING APPLIANCES

The National Fuel Gas Codes (NFPA #54) provide guidelines for the venting of heating appliances, governing the installation of specific appliances. While NFPA #54 is a good guide, the final jurisdiction is the applicable local authority.

According to NFPA #54, the following heating appliances must be vented:

1. Steam and hot water boilers, warm air furnaces, floor furnaces and wall furnaces.
2. Unit heaters and duct furnaces.
3. Room heaters listed only for vented use. Room heaters listed as "vented" or "*unvented*" units are subject to approval of the authority having jurisdiction.
4. Appliances equipped with conversion burners.
5. Other listed appliances which have draft hoods supplied by the appliance manufacturer.
6. Unlisted appliances except specialized equipment of limited input (laboratory burners or gas lights).

The venting of the above appliances must be done in a safe manner. Local, state, and national codes generally reflect practices that have been determined to be safe and effective over long periods of time. NFPA #54 requires that venting systems be engineered and constructed to develop a positive flow which is adequate to remove flue gases to the outside. Also, when the appliance requires a draft for proper operation, the venting system must satisfy the draft requirements in accordance with the manufacturer's recommendations. The ability of an appliance to vent satisfactorily when connected to a minimum venting system is determined through certification tests in accordance with American National Standards and Underwriters Laboratory standards. Appliance designs bearing A.G.A. Laboratories' seal have been design certified under American National Standards. Code requirements which govern the design and construction of venting systems and appliance certification ensure minimum safety performance. Gas vents must *always* be installed in accordance with the requirements of their UL listing and the manufacturer's recommendations.

Termination of Gas Vents

The termination of a gas vent must be at least 2 feet above the highest point where it passes through a roof. Also, it must be at least 2 feet above the highest part of the roof within a horizontal distance of 10 feet. The vent should not terminate adjacent to a wall or below eaves or parapets (see Figure 3-15 a,b,c,d). Wind flow over roof structures often causes localized pressure disturbances and downdrafts. The vent termination must be located where these effects are minimized. The height of Type B vents must not be less than 5 feet in vertical height above the highest connected appliance draft hood. For Type BW vents (vented wall furnace), the minimum height is 12 feet from the base of the heater (see Figure 3-16 a,b).

Multistory Vents

Gas vents are frequently used in multistory applications where each vented appliance connects to a common vent at a different level of a structure. Figure 3-17 a,b, illustrates a multistory vent arrangement. The connectors and vent must be designed so they perform properly with any one appliance or any combination of appliances operating. In the design of multistory vents, it is important to separate gas appliances from occupied spaces. Also, adequate ventilation should be provided in the appliance installation area. In the remote case that blockage occurs, all appliances below the blockage will vent through their draft hood relief openings.

Support and Marking

Vents must be adequately supported for the design and weight of the vent materials used and still maintain the proper distance from combustible materials. Adequate fasteners should be used to prevent joint separation and physical damage to the vents. In areas where solid and liquid fuels are used extensively, gas vents shall be plainly and permanently labeled as unsuitable for venting appliances burning these liquid and solid fuels. Specific terminology is provided in NFPA #54, along with guidelines for locating labels.

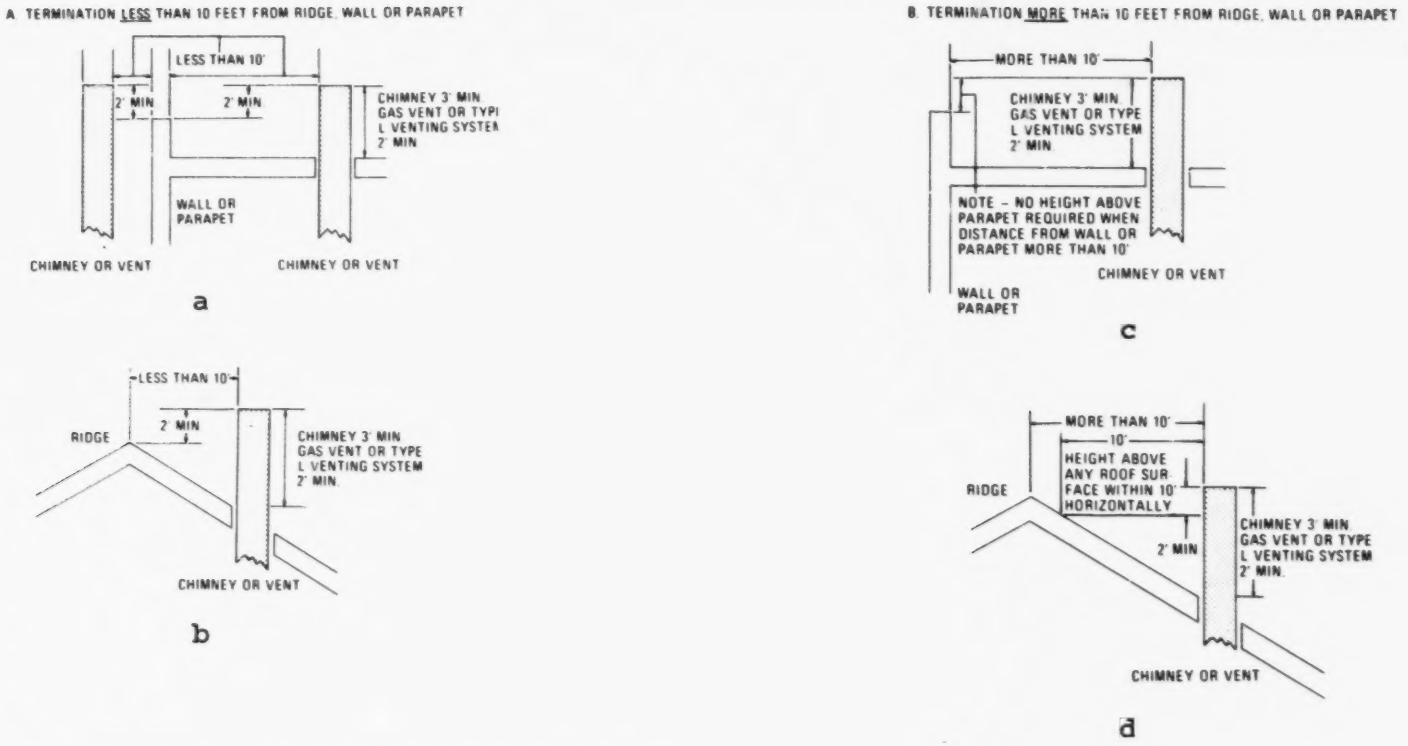
Vent Sizing

NFPA# 54 states that vents shall be sized and constructed in accordance with approved engineering methods. Tables have been developed which relate vent height and lateral distance to maximum appliance input rating and various sizes of gas vents. For example, Figure 3-18 shows a typical single appliance gravity type vent system. By determining dimensions H and L shown in Figure 3-18 and knowing the input rating of the appliance

BEST DOCUMENT AVAILABLE

FIG. 3-15

CORRECT VENT TERMINATIONS



to be vented, a vent size can be selected from the Tables in Appendix 1-D of NFPA #54. Notes accompanying these tables give guidelines and limitations on their use, and procedures for calculating the effect of other factors which may affect vent size.

Tables are also given for several types of vents and for single and multiple appliance installations. Care should be taken that reference is made to the correct table. Take the following appliance as an example:

Input rating - 120,000 Btu/hr. Vent height (H) - 8 feet.

Draft hood size - 6 inches . Vent lateral length (L) - 2 feet.

Vent Material - Type B (double wall).

Connector material - Type B (double wall).

The proper appliance table to use would be 1-D1. A 5-inch diameter vent connector would be adequate. However, a note accompanying the Table prohibits sizing a vent smaller than the draft hood size if the vent height is less than 10 feet. The proper vent size would be 6 inches; the same size as the appliance draft hood outlet.

Generally, the vent connector size should not be smaller than the draft hood outlet size. While this is a general rule, in some cases, the vent connector size may actually be smaller than the draft hood outlet size. This condition normally occurs when the chimney height is *greater* than 10 feet and the capacity of the venting system is greater than the input of the appliance.

BEST DOCUMENT AVAILABLE

FIG. 3-16A

FIG. 3-16B

MINIMUM VENT HEIGHTS

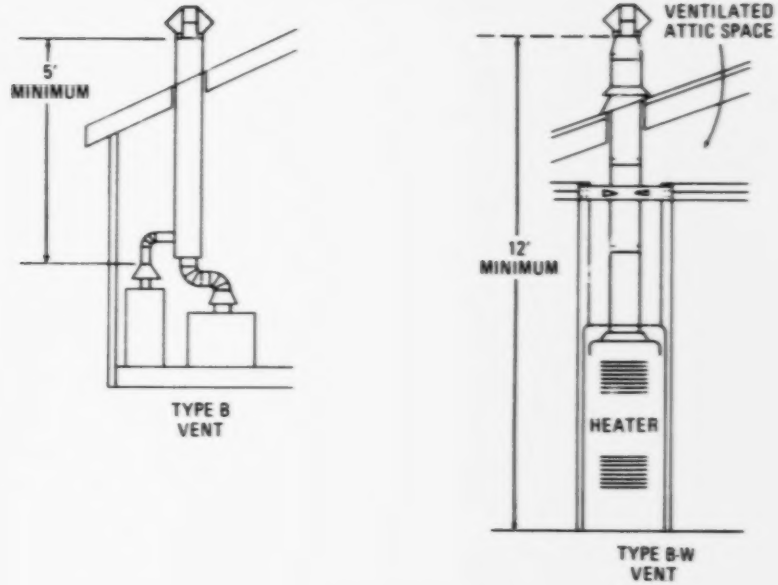
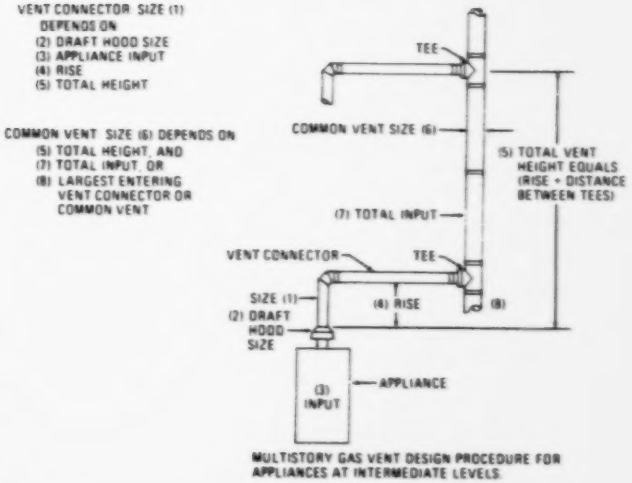


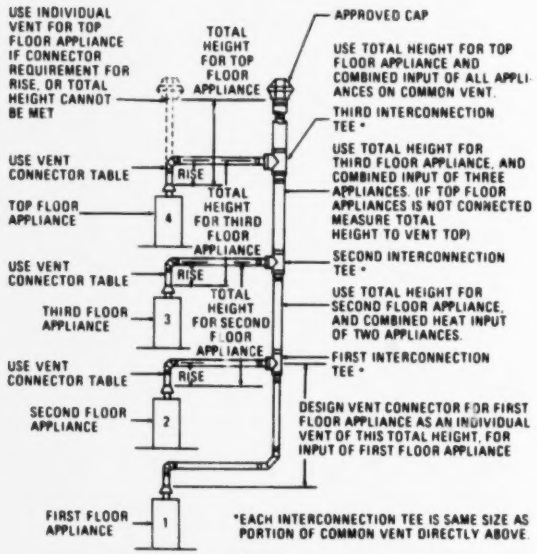
FIG. 3-17A

MULTI-STORY VENT SYSTEMS



MULTISTORY GAS VENT DESIGN PROCEDURE FOR APPLIANCES AT INTERMEDIATE LEVELS

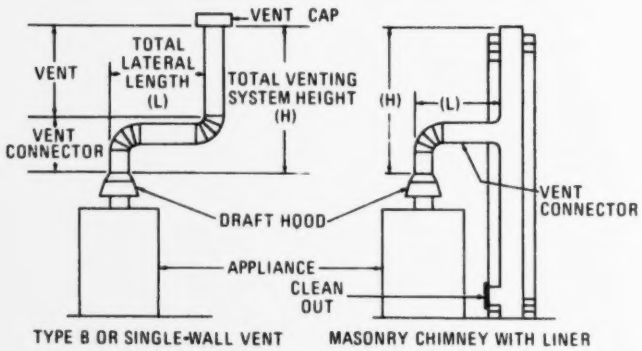
FIG. 3-17B



PRINCIPLES OF DESIGN OF MULTISTORY VENTS USING VENT CONNECTOR AND COMMON VENT DESIGN TABLES

FIG. 3-18

SINGLE APPLIANCE GRAVITY VENT SYSTEM



TYPE B OR SINGLE-WALL VENT

MASONRY CHIMNEY WITH LINER

BEST DOCUMENT AVAILABLE

When attaching two or more vent connectors to a common vent, (Figure 3-19), the smaller size connector should enter the common vent at the highest level possible (maintaining proper clearances). Connectors should not enter the common vent at the same level, facing each other. Connector Tees should be the same size as the common vent as shown in Figure 3-20.

FIG. 3-19

VENT CONNECTORS

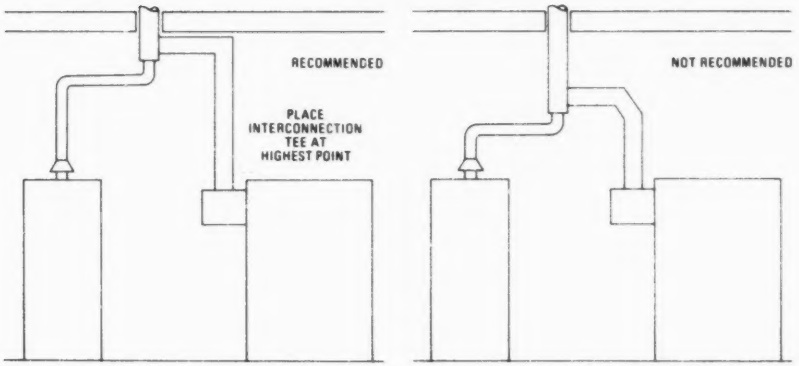
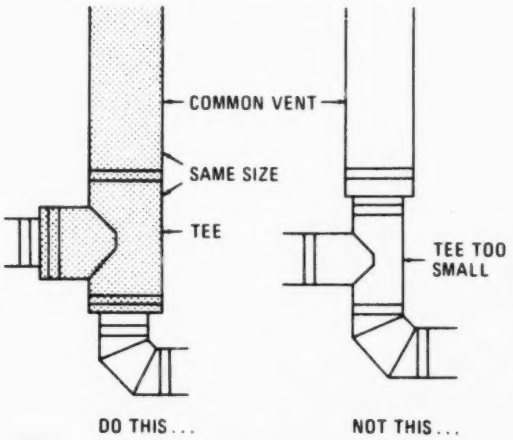


FIG. 3-20

TEES IN COMMON VENT



In addition to the use of the vent sizing tables, the industry has adopted an alternate method for determining that an existing vent is properly sized. If the use of the alternate procedure results in a vent size, *less than* the size of the actual vent, sizing tables must be consulted to ensure that the actual vent size is correct.

The alternate procedure has two requirements; First, the size of the appliance vent connector must be equal to or larger than the size of the appliance draft hood outlet. Second, if the venting system uses a common vent, the *area, not the diameter*, of the common vent must be equal to the *area* of the largest vent connector plus 50% of the area of each smaller connector.

To determine the area of a vent, you must square the diameter then multiply it by .785. For example, the area of a 6 inch vent would be $(6)^2 \times .785 = 28.26$ sq. inches. In the case of smaller vent connectors, the same equation would be used, then the answer would then be multiplied by 50%. To convert the area back into vent diameter, divide .785 into the area. Always use the next larger vent size if the answer yields a fraction. For example, if an equation yields a 6.363 inch vent size, the actual vent size *must* be 7 inches.

• CHIMNEYS

Masonry or metal chimneys shall be built to applicable building codes. Factory-built chimneys listed by UL shall be installed in accordance with their listing and the manufacturer's instructions.

Termination

NFPA #54 requires that a chimney extend at least 3 feet above the highest point where it passes through a building's roof and at least 2 feet higher than any portion of a building within a horizontal distance of 10 feet. Figure 3-15 illustrates these requirements. Chimneys must also extend at least 5 feet above the highest connected draft hood outlet or flue collar.

Sizing

Procedures for sizing of chimneys used as gas vents are identical to those for sizing gas vents. Tables 1-D3 and 1-D6 provided in Appendix 1-D of NFPA #54 apply to chimneys. In addition, Table 1-D7 gives equivalent circular vent sizes for rectangular chimney liners of various dimensions.

When a gas appliance vent connector is to be connected to an existing chimney, a careful and complete inspection should be performed to determine the installation will perform properly. The chimney passageway should be clear and free of obstructions. Cleanouts and Tee fittings used as cleanouts or condensate drains should be tightly constructed to prevent air from entering the chimney.

BEST DOCUMENT AVAILABLE

Masonry chimneys, particularly older ones and those designed to vent the combustion gases of appliances burning solid or liquid fuels, should receive special attention. If the chimney is unlined or local experience indicates that condensate may be a problem, an approved liner or another vent should be installed. If inspection of the chimney reveals that it is not suitable for the intended application, it should be rebuilt, relined, or replaced with suitable vent materials.

It should be noted that a vent connector shall not be connected to a chimney flue serving a fireplace unless the fireplace opening is permanently sealed. In addition, in some areas of the country and at certain outside temperatures, the vent cap openings of gas vents in a Class "A" (masonry chimney) may freeze or rust closed. The condensation of water in the flue gases creates this condition. As a result, it may become necessary to remove the vent cap.

• SINGLE WALL METAL VENTS

NFPA #54 permits the use of single wall metal pipe to construct vents which run directly from the space in which the appliance is located through the roof or exterior wall to the outer air. In this case, special use of roof thimbles and flashings must be considered. State and local codes should always be consulted. In many areas, single wall metal vents are not permitted.

Termination

Figure 3-15 illustrates the termination requirements for single wall metal pipe. Like gas vents, the single wall metal vent must extend at least 5 feet above the highest connected appliance draft hood or flue collar, 2 feet above the highest point where it passes through a roof of a building; and 2 feet above any portion of a building within a horizontal distance of 10 feet. A vent pipe passing through a roof shall extend, without interruption, through roof flashing, roof jack, or roof thimble. Single wall metal vents must not originate in an unoccupied attic or concealed space and must not pass through an attic, inside wall, concealed space, or floor.

Clearance from Combustibles

Figure 3-21 shows minimum clearances from combustible materials. These clearances may be reduced only when proper protection is provided. Where single wall metal pipe passes through an exterior wall or roof constructed of combustible material, it shall be guarded at the point of passage by a thimble which provides the required clearance.

Sizing

Single wall metal vents can be sized in a manner similar to gas vents by utilizing Tables 1-D2 and 1-D5 in Appendix 1-D of NFPA #54. Any shape of pipe may be used provided the effective area is equal to the effective area of the required round vent, and the minimum internal dimension is not less than 2 inches. If used, a roof cap or roof assembly must have a venting capacity not less than that of the pipe.

• VENT CONNECTORS

Figure 3-18 illustrates a typical vent system with draft hood, vent connector, and vent. Vent connectors are required whenever the vent cannot be connected directly to the appliance.

Vent connectors used for heating appliances with draft hoods must be constructed of materials having a resistance to corrosion and heat not less than that of No. 28 galvanized sheet steel, or No. 26 B&S gauge copper, or No. 24 B&S gauge aluminum. Where appliances are listed for use with Type B or Type L vents, these materials may be used to construct vent connectors. Vent connectors for other appliances must be constructed of materials equal to No. 24 galvanized sheet steel or No. 22 B&S gauge copper.

Sizing

Size of vent connectors can be determined by referring to Tables 1-D1 through 1-D6 in Appendix 1-D of NFPA #54. *As an alternative method,* vent connectors can be sized to have an effective area not less than the area of the draft hood outlet. When a vent connector is oversized to overcome installation limitations, the size increase must be made at the appliance draft hood outlet.

Multiple Connectors

Where two or more vent connectors enter a common vent, the smaller connector should enter at the highest point, allowing for available headroom and clearance from combustible materials. If two or more gas appliance vents enter a common vent connector, the smaller connector should also be located at the highest level possible. Common vent connectors can be sized using the same procedures for sizing vents serving multiple appliances.

Clearance from Combustibles

Minimum clearances from combustible materials are shown in Figure 3-21. NFPA #54 reduces these distances where noncombustible materials are used. Where vent connectors pass through walls or partitions of combustible materials, thimbles must be provided. Requirements for thimble sizing are given in NFPA #54.

BEST DOCUMENT AVAILABLE

FIG. 3-21

CLEARANCES FOR CONNECTORS

Appliance	Minimum Distance from Combustible Material: Listed Type B Gas Vent Material	Listed Type L Venting System Material	Connectors of Other than Type B or Type L Material
Listed appliances with draft hoods and appliances listed for use with Type B Gas Vents	as listed	as listed	6 inches
Boilers and furnaces with listed gas conversion burner and with draft hood	6 inches	6 inches	9 inches
Appliances listed for use with Type L venting systems	not permitted	as listed	9 inches
Residential Incinerators	not permitted	9 inches	18 inches
Unlisted appliances with draft hood	not permitted	6 inches	9 inches
Appliances other than those above	not permitted	9 inches	18 inches

Joints, Pitch, Length

Vent connectors constructed of listed materials shall be assembled using the method recommended by the manufacturer. Joints in other than listed materials shall be securely fastened by sheet metal screws or other approved methods.

Vent connectors should be installed without any downward pitch from the appliance and without sags or dips. Further, all horizontal runs including vent connectors attached directly to side outlet draft hoods, shall be pitched upward from the appliance at least ¼ inch per foot.

Since the flue gases are hot and tend to rise, a downward pitch in the vent connector acts as a trap and flue gases may spill out of the appliance draft hood. In extreme cases, venting action may totally cease.

Horizontal runs resist flow and do not contribute to the draft action. The horizontal run of a vent connector should be as short as possible and with as much upward pitch as possible. The maximum horizontal length of a single wall vent connector from a single appliance shall not exceed 75% of the height of the gas vent or chimney. The maximum horizontal length of Type B double wall vent from one appliance shall not exceed 100% of the height of the gas vent or chimney.

Chimney and Fireplace Connections

In entering the flueway of a masonry or metal chimney, the vent connector shall be installed above the extreme bottom to avoid stoppage. The installer should be sure the vent connector does not extend so far into the flueway that it restricts the space between its outlet and the opposite wall of the flueway. If a thimble or slip joint is used, the vent connector shall be firmly attached to prevent the vent connector from falling out. A vent connector shall not be connected to a chimney serving a fireplace, unless the fireplace opening is permanently sealed. If unsealed, a negative pressure in the room where the fireplace is located can cause the appliance or fireplace flue products to flow into the room.

• TROUBLESHOOTING

In most cases, problems caused by the vent system are due to one of three conditions: incorrect sizing of the vent system, improper installation, or inadequate air supply. On each venting problem:

1. Check the vent sizing.
2. Examine the entire vent system for an obvious fault, such as disconnected joints or crushed vent sections or cap.
3. Check all vent and air openings to make sure they are free from any obstructions.
4. Visually inspect the system for indications of improper design and installation.

Some of the more obvious indications of improper design and installation are:

1. Vent pipes smaller than the outlet of the draft hood.
2. The use of more than two 90° elbows in a run to a vertical vent.
3. A vent connector from one appliance attached to a second vent from a second appliance.
4. Connection of two appliances to a common vent through opposing ends of a "Tee" at the bottom of the vertical common vent.
5. Connection of two appliances to the common vent with a "Y" connector.
6. A long lateral or horizontal run of the vent connector.

BEST DOCUMENT AVAILABLE

Troubleshooting can be accomplished more easily if the problem's symptoms have been observed. Some common symptoms of poor vent system operation are condensation, spillage, and chronic pilot outage.

Condensation

When uninsulated single wall vents are used, high heat losses can cause the gases to be cooled below their dew point temperatures. When this occurs, water condenses on the inside of the vent. Condensation can also occur in heavy, single wall vents made of cement-asbestos or terra cotta. In this case, the gases are cooled because these heavy materials absorb large amounts of heat before they equalize to the temperature of the flue gases. To correct this condensation problem, insulate the single wall vents using at least one inch of glass wool or its equivalent. To correct condensation in terra cotta pipe, replace with Type B vent. Vents located outside, especially in cold climates, may exhibit condensation even if they are of Type B construction. Almost certainly, condensation will occur in single wall vents installed outside in cold weather. Condensation may occur in vents located in other areas where the surrounding air is not warmed. To correct condensation in outside vents, replace single wall pipe with Type B or add appropriate insulation.

Spillage of Combustion Products

Spillage from an appliance draft hood may cause condensation on windows or walls or create noticeable odors. Spillage can be caused by an incorrectly sized vent system, an improperly installed vent system, blockage of the vent system, or a downdraft in the vent. If the vent is too small or too short, it will not be able to handle all flue gases. Spillage will result. If the vent is too large, an excessive amount of dilution air will enter the vent, cool the combustion products, and reduce the draft in the vent, causing spillage. Check the vent size and height with the appropriate tables and change if needed. Also check for causes of downdraft. The vent cap must have the capacity to handle the total of all appliance inputs. The vent cap is normally the same diameter as the vent. If the vent cap is too small, it can cause flue products to back up and spill from the appliance draft hood. Check the size and capacity of the vent cap and replace if needed. In some cases, exhaust fans can create a negative pressure which may result in a similar symptom.

Lengthy lateral runs without any upward pitch or with sags can cause extra resistance to flow. A small amount of sagging can lower the draft to a point where a slight spillage occurs. If possible, shorten the lateral run, install at the correct pitch, and straighten out any sags in the lateral run.

Elbows in vent piping increase resistance to combustion gas flow passing through the vent. Usually, two 90° elbows can be tolerated in a vent system. If more than two are used, the system may not perform properly. Redesign the vent system to eliminate as many elbows as possible, or change the vent arrangement to improve the draft.

In cases where occasional spillage results, the flow resistance in the vent is at a marginal point. A slight reduction of this resistance may solve the problem. If a lateral run is not pitched upward properly (at least ¼ inch per foot from the appliance to the vent), too much resistance may be a result. Check and correct all lateral runs that are not pitched properly.

Where several appliances are connected to a common vent which is not properly sized, spillage can occur when one (or more) of the appliances is used. Recheck the size of any common vent using the proper table and change as needed.

Spillage can occur if the smaller appliance (i.e., water heater) in the multiple vent system has too short a connector rise or too long a lateral run. When the appliance operates alone, it may not generate sufficient draft to overcome the resistance and displace the large amount of cooler air in the common vent. The heat exchanger surface of a water heater is water backed. As a result, the flue gases take longer to reach a normal operating temperature. On multiple vent systems, locate the smaller appliance as close to the common vent as possible and/or keep the connector rise as steep as possible.

Chronic Pilot Outage

For appliances with draft hoods, pilot outage can be caused by improper vent termination. The vent should terminate in accordance with previously stated rules. A vent with inadequate height may also cause a problem. Both of these problems can be corrected by following the rules of proper vent sizing and design.

Excessive air flow through a direct vent appliance, when the vent hood is exposed to high winds, often causes pilot outage. Make sure all vent and air intake connections are tight and that there are no leaks or restrictions in the vent system or heat exchanger. Replace or repair as necessary.

If the appliance is located near an outside corner of the house or near a projection on the outside wall, wind may cause high pressures at the vent cap. Relocate the appliance if possible. Shield the appliance from wind effects. (Caution: Do not place windshields so close to the vent cap that the appliance operation is affected.) Replace the cap with another, making sure that the appliance has been listed for use with the new cap.

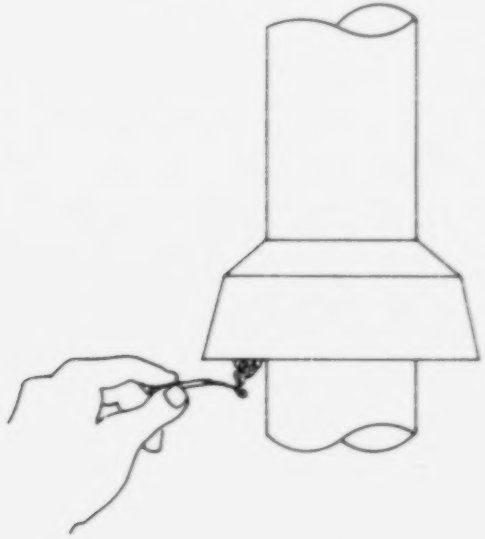
Intermittent pilot outage is abnormal and therefore should be investigated. The malfunction should be determined and corrected. A spark or electronic pilot relight system may correct a chronic pilot outage problem, but it does not necessarily change the *cause* of the problem. Only ignition systems which have been design-certified and listed for use with the appliance can be substituted.

BEST DOCUMENT AVAILABLE

• TESTING

The simplest way to test a vent system for spillage is by using smoke. After the appliance has been operating for 5 to 10 minutes, hold a cigarette or smoking match near the appliance draft hood opening as shown in Figure 3-22. If the smoke is drawn into the opening, the vent is performing satisfactorily. If the smoke is not drawn into the vent, then spillage is probably occurring at the appliance draft hood.

FIG. 3-22
SPILLAGE TEST



In trying to determine which appliance vent is spilling into the dwelling, first check each appliance separately for spillage. If some, but not all, appliances are venting properly, then spillage is probably due to problems in the vents or vent connectors immediately above the appliances where the spillage is occurring. If all appliances are venting properly, it is likely that leakage is occurring in the vent system and a smoke test should be performed. If none of the appliances vent properly, then problems above the highest connection to the vent system should be investigated. Repair or replace as necessary.

In order to test for *leakage* in the vent system, a "smoke gun" is often used. The smoke gun cartridge discharges a chemical into the vent which gives off a smokey vapor. For best results, the venting system should be pressurized during this test (i.e., capped). As the smoke rises through the vent system, it will leak out and can be detected visually. Smoke testing should start from the lowest point in the section of vent to be tested.

• COMBUSTION PRODUCT SAMPLING

The main objective of combustion product sampling and testing is to maximize safe and efficient appliance operation. Combustion product sampling is normally performed when an analysis of the flue products is desired or necessary, to determine proper burner adjustment and/or safe operation of an appliance. Because of the wide variety of appliances, venting systems, temperatures and conditions, it is impossible to establish a general rule for combustion testing which is common to every application. The following four categories of testing and sampling are applicable to average conditions and applications.

1. Maximum allowable level for carbon monoxide (CO) is generally no more than .04%. The test should be taken before the draft hood.

2. Average limits on carbon dioxide (CO_2) are generally:

   a. Atmospheric burners - generally not less than 6% nor more than 7.5%.

   b. Power burners - generally not less than 7.7% nor more than 9.2%.

   These tests should be made before the draft hood.

3. Average limits on flue gas temperature are generally not less than 200°F and not more than 450°F gross value.*All tests should be made 6" below the draft hood.

4. Average limits on oxygen (O_2) are generally not less than 7.5% and not more than 10%. All tests should be made before the draft hood.

*Note: Flue gas temperature is calculated by two methods, either gross or net temperature. The gross temperature is the total flue gas temperature, *including* the room temperature where the appliance is located. Often the flue gas temperature is expressed as net, that is, the temperature after subtracting the room temperature. The actual temperature measured before the draft hood, in the previous rule, is gross temperature.

The primary purpose of testing is to limit production of dangerous CO and thus ensure safe operation. However, as energy has become more costly, energy efficiency testing has gained importance. Combustion testing is a means to meet both objectives.

Products of Combustion

The products of complete combustion of fuel gases are CO_2 and water vapor. Since combustion is a chemical reaction between the fuel gas (hydrocarbon) and oxygen, the amount of CO_2 produced by combustion can be accurately calculated. This theoretical, or *ultimate* amount of CO_2 is expressed as a percentage of all combustion products, 11.7% to 12.2% for natural gas, 14.0% for butane, and 13.7% for propane.

BEST DOCUMENT AVAILABLE

Excess air is always provided so safe, complete combustion will occur. Because excess air dilutes the CO_2 produced, we can use the concentration of CO_2 as an indicator of the amount of excess air supplied to the appliance. It is generally accepted practice to provide quantities of excess air that will result in from 70% to 80% of the ultimate CO_2 concentration. For natural gas with 11.8% ultimate CO_2, this means CO_2 concentration in the flue gases of about 7.5% to 9% for atmospheric burners and 7.7% to 9.2% for power burners.

Since combustion utilizes oxygen in the air to produce CO_2 and water, the amount of oxygen remaining in the combustion products can also be used as an indicator of the amount of excess air provided. Figure 3-23 relates the concentrations of CO_2 and O_2 to the percentage of excess air in natural gas combustion.

Combustion Efficiency

Maximum combustion efficiency is a measure of the amount of useful heat produced by the appliance related to the total heat produced by the burning of the gas, assuming complete combustion and no excess air. *Stack loss* is a measure of heat loss out the vent from the hot combustion gases. Combustion efficiency (expressed as a percentage) plus stack loss (expressed as a percentage) equals 100% of the total heat produced by the combustion process.

Combustion efficiency can be determined if the CO_2 concentration (as a measure of excess air flow) and the net temperature of the flue gases are known. With this information, combustion efficiency can be determined directly from published tables and curves or by using a slide rule device specifically designed for this purpose. Gas heating appliances should always be capable of at least 75% combustion efficiency unless specifically designed for high efficiencies. Operation at efficiencies higher than 80% may create conditions which affect vent draft, form corrosive condensate in the vent or heat exchanger, or create other operational maintenance difficulties.

CO-Free Combustion

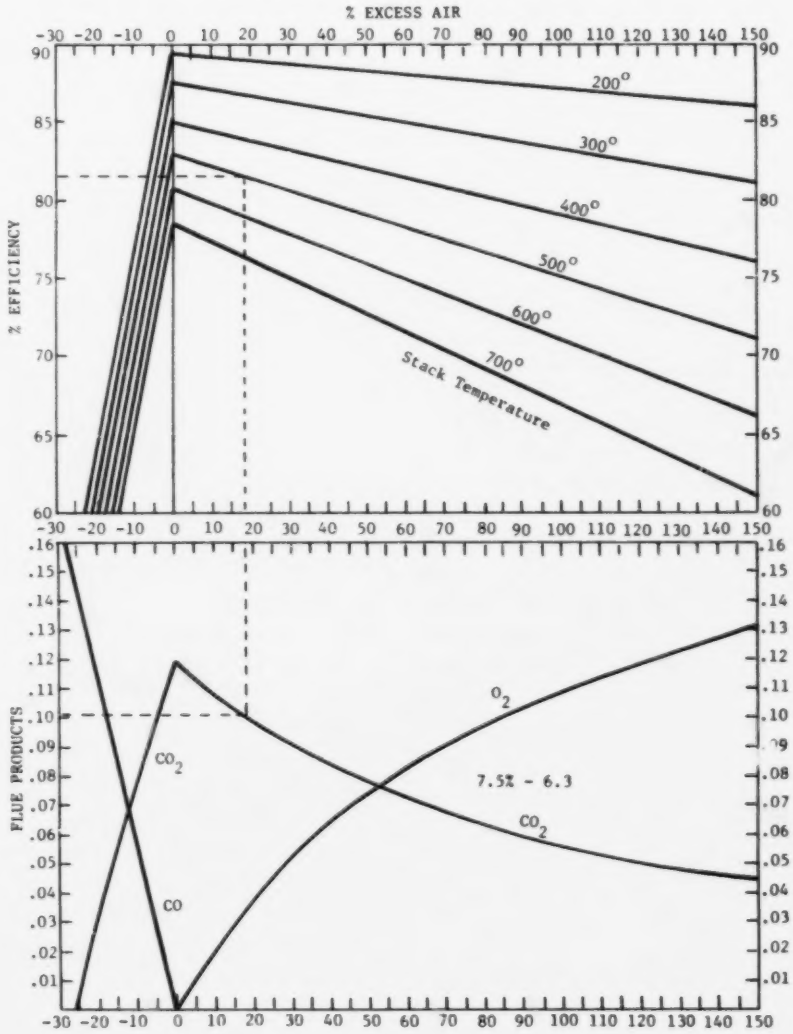
It is possible for an appliance to produce carbon monoxide even if excess air, CO_2 and O_2 are within limits. This can occur if the flame is partially quenched by contact with cold surfaces, leaking heat exchangers or incomplete combustion. Because of the hazards related to carbon monoxide it is essential that combustion products be tested for it, even when all other tests indicate combustion is complete. Again, the maximum allowable level of CO is generally no more than .04% in an air-free sample of flue gas before the draft hood.

Sampling and Measurement

Before any sampling or testing is attempted, the appliance should be operated for several minutes so that test results are respresentative of actual appliance operation.

FIG. 3-23

COMBUSTION EFFICIENCY CHART



BEST DOCUMENT AVAILABLE

CO_2 and Excess Air Testing

CO_2 tests can be made with commercially available test kits. Procedures recommended by kit manufacturers should be followed closely for best results. Most kits provide a sampling tube and rubber bulb which, when squeezed, draw combustion gases into the test unit. The sample must be taken from the inlet side of the draft hood as shown in Figure 3-24. A typical procedure for sampling and testing is shown in Figure 3-25. With a similar test kit, O_2 measurements can be made in the same manner.

Flue Gas Temperature Testing

Flue gas temperature must be known, along with CO_2 concentration, to determine combustion efficiency. To measure the flue gas temperature, a thermometer should be inserted into the flue gases 6" below the inlet of the draft diverter. Leave the thermometer in the vent until the reading reaches a maximum value. Generally, the flue gas temperature should not be less than 200°F and not more than 550°F.

FIG. 3-24

CO_2 CHECK

Checking CO_2 of gas-designed furnace (sampling tube inserted through draft diverter; flue gas temperature test can be made at same point)

Carbon Monoxide Testing

Carbon monoxide (CO) tests can be made in a manner similar to CO_2 measurements. Commercially available kits typically contain a CO-sensitive chemical which discolors to indicate CO concentration. Measurements are usually specified on an "*air-free*" basis. This means that the value obtained from testing is adjusted to eliminate the dilution effect of excess air in the combustion gases. Since the ratio of the actual CO_2 to ultimate CO_2 is determined by the amount of excess air, the measured CO value can be adjusted by this ratio to obtain an "air free" concentration.

$$\text{Air-free CO} = \text{measured CO} \times \frac{\text{ultimate } CO_2}{\text{actual } CO_2}$$

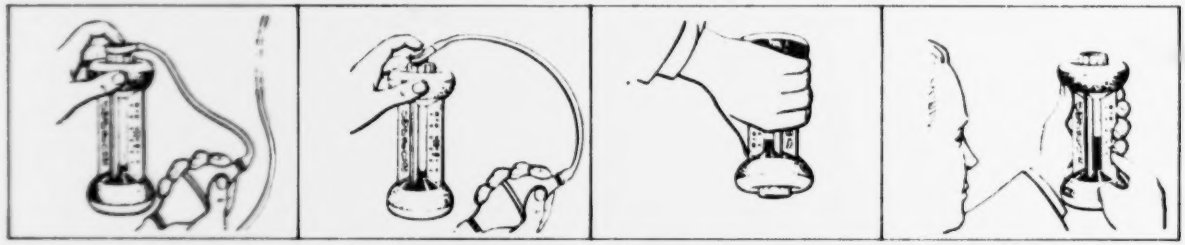
For example, for natural gas with an actual measured CO_2 of 8.8% and a measured CO concentration of 0.03% . . . .

$$\text{Air-free CO} = .03 \times \frac{11.7}{8.8} = .04\%$$

If CO concentration is found to be excessive, immediate action should be taken to correct the problem, or prevent the use of the appliance until the problem has been corrected. Typical causes of excessive CO are insufficient primary air (which should also be indicated by yellow flame and CO_2 concentration), flame impingement on cool surfaces, and overrating of the appliance.

FIG. 3-25

PROCEDURAL STEPS FOR CO_2 AND O_2 CHECK



1. Push rubber connector down—then squeeze bulb 18 times.

2. Lift finger from rubber connector—this seals Fyrite.

3. Turn bottom side up and back again; twice on CO_2, four times on O_2.

4. Read fluid level on scale for percentage of gas.

BEST DOCUMENT AVAILABLE

NOTES:

SECTION 4

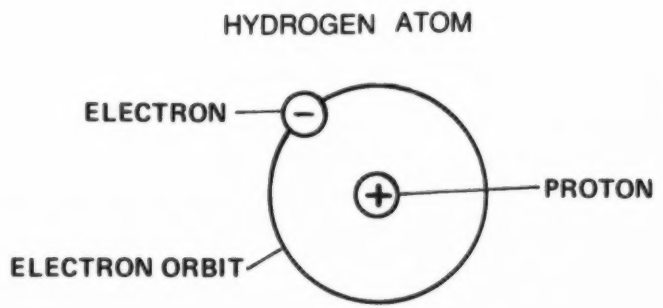
BASIC ELECTRICITY REVIEW

BASIC ELECTRICAL THEORY

The study of electricity requires a fundamental knowledge of matter and atomic structure. Matter is anything which occupies space and has weight. Matter can be in the form of a liquid, solid, gas, or any combination of the three. The fundamental building block of matter is called the *atom*. The atom is the smallest particle of matter to have the characteristics of a specific substance. For example, atoms of oxygen exhibit the same properties which we observe in large quantities of oxygen.

The atom is made up of three basic components: the *proton*, the *neutron*, and the *electron*. The proton is a particle having a relatively large mass and a positive charge. The neutron has roughly the same mass as a proton but has no electrical charge. Protons and neutrons are clustered together to form the nucleus, or center of the atom. The electron is a particle of relatively small mass and negative charge which moves in an orbit around the nucleus, similar to the orbit of the moon around the earth. Figure 4-1 shows the simplest atom known to man, the hydrogen atom. This atom consists of one proton and one electron. The electron is held in its orbit by the force of attraction between the positively charged proton and the negatively charged electron. The overall charge of the atom is neutral since it has the same number of positively and negatively charged particles. In more complex forms of matter, electrical imbalances may occur. Basically, an electrical imbalance occurs where there are excesses or deficiencies of electrical charges.

FIG. 4-1



Electron Flow/Potential Force

Electricity is the movement of electrons from a body which contains an excess of electrons to a body which has a deficiency of electrons. This movement of electrons is illustrated in Figure 4-2. A body with a number of free electrons is connected to a body with a smaller number of free electrons by a copper wire. As shown by the arrows, electrons will flow from the body with the most electrons to the body with fewest. Electron flow in this fashion is called an *electric current*.

The amount of electron flow from Body A of Figure 4-2 to Body B depends on the difference of the number of free electrons between A and B. The greater the difference of free electrons, the greater the flow. The less the difference, the less the flow. This movement of free electrons from A to B will continue until each body contains the same number of free electrons. The bodies will then be equally charged and electron flow will stop.

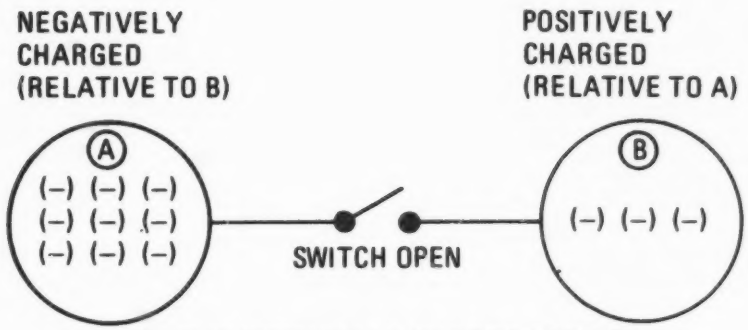
The relative charge on Bodies A and B of Figure 4-2 can be considered as a difference in electrical pressure between these two points, known as the *potential difference*. A water analogy in Figure 4-3 illustrates the potential difference and subsequent electron flow between two points.

Consider the two reservoirs shown in Figure 4-3a, connected together, but with a closed valve in the connecting line. Reservoir A is filled with water to a higher level (more electrons) than reservoir B. As a result, the water in reservoir A exerts a greater pressure on its side of the valve than the water in reservoir B. This situation is comparable to a negatively charged and positively charged body isolated from each other by an open switch. In Figure 4-3b, the valve is opened. The difference in water pressure causes

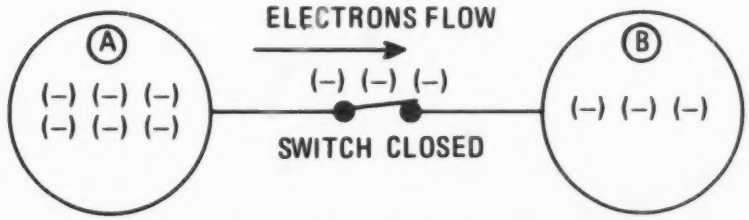
BEST DOCUMENT AVAILABLE

FIG. 4-2

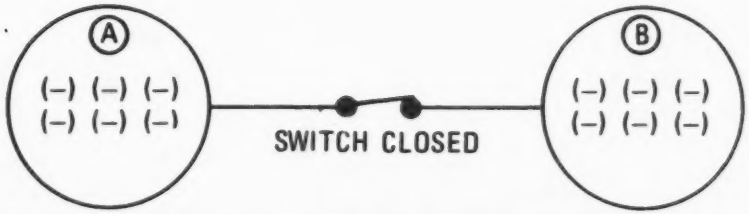
ELECTRON FLOW



A. TWO ELECTRICALLY CHARGED BODIES



B. BODIES CONNECTED. FREE ELECTRONS FLOW FROM A TO B.



C. BOTH BODIES CONTAIN SAME NUMBER OF FREE ELECTRONS. FLOW OF FREE ELECTRONS STOPS.

water to flow from reservoir A into reservoir B through the connecting line and valve. This condition is like closing a switch. Connecting two electrically charged bodies results in electron flow from the more negatively charged one to the other one. When the water levels in reservoirs A and B reach the same height, Figure 4-3c, the difference in pressure has become zero (the pressures on either side of the valve are the same) and water flow stops. Similarly, electron flow between two electrically-charged bodies will stop when each body contains the same number of free electrons.

Thus far we have been dealing with static electricity, in which two bodies are charged only once, and then interact with each other when connected together. To relate this simple case to practical electrical *circuits* which are used in gas appliances, we must consider two additional factors. First, the natural state of atoms is balanced. Hence, some work must be done or energy must be used to create a potential difference between two bodies.

In the water analogy shown in Figure 4-3, we simply stated that the two reservoirs were filled initially to two different levels. Some work or energy must have been applied to fill these reservoirs. Similarly, electricity cannot be generated without the use of some other form of energy. Another form of energy, whether it be mechanical, chemical, etc., must be converted to electrical energy.

When dealing in practical electrical circuits, the second factor to consider is that the flow of electrons must be constant when the circuit is in use, rather than the one-shot transfer discussed thus far. The flow of electrons in a circuit is called *current*. We measure electrical current in amperes, or amps. It is the ability to produce this constant current which makes electricity a useful form of energy. In order for the current to be continuous some source must maintain a potential difference between two points in the circuit. Such a source provides what is commonly referred to as an *electromotive force*, abbreviated as emf, which represents the same thing as a potential difference, or voltage.

ELECTROMOTIVE FORCE

The source for emf can be illustrated by expanding the water analogy to include a pump, as shown in Figure 4-4.

In Figure 4-4, the difference in water height between the reservoirs produces a potential difference. With the valve open, water flows from A to B as shown. However, if the pump (representing the source of emf) withdraws water from B and returns it to A at the same flow rate as water is flowing from A to B through the valve, the water levels in the two reservoirs will remain unchanged. Water will continue to flow around the system at a constant rate as long as the pump is in operation. The potential difference between A and B will remain constant.

BEST DOCUMENT AVAILABLE

WATER FLOW ANALOGY

FIG. 4-3A

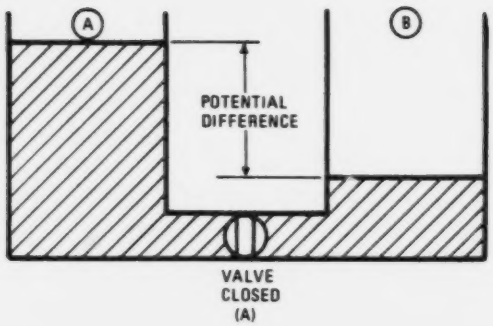


FIG. 4-3B

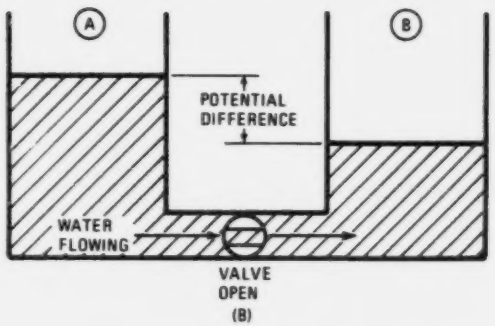
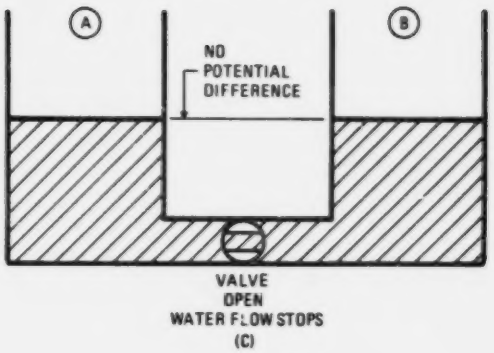


FIG. 4-3C



In the electric circuit in Figure 4-4b, an emf source (such as a generator or battery) "pumps" electrons, and thereby maintaining a potential difference between points A and B so that electrons flow continuously around the circuit. Note that some external energy or work must be exerted at the emf source to keep it operating, just as work must be expanded to drive the pump in Figure 4-4a.

Resistance to Flow

Thus far electricity has been considered in terms of flow of electrons (current) and potential difference (emf or voltage). One other fundamental property, *resistance*, must be understood to provide a foundation for working successfully with electrical devices.

WATER FLOW WITH EMF SOURCE

FIG. 4-4A

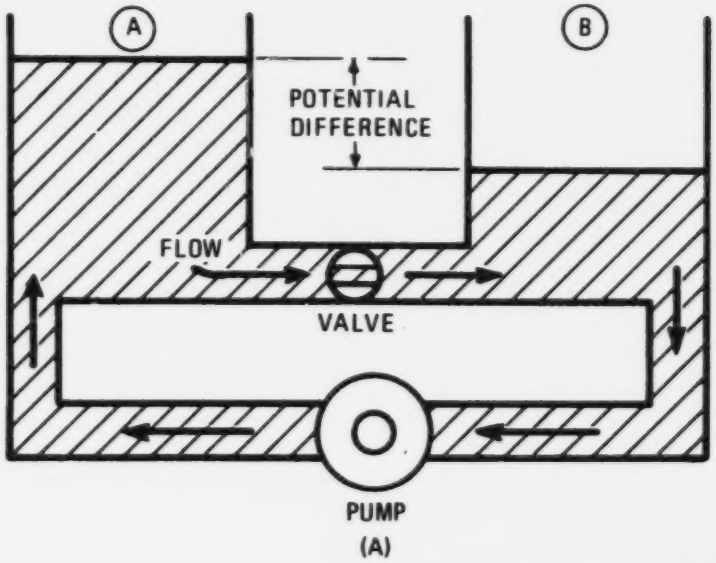
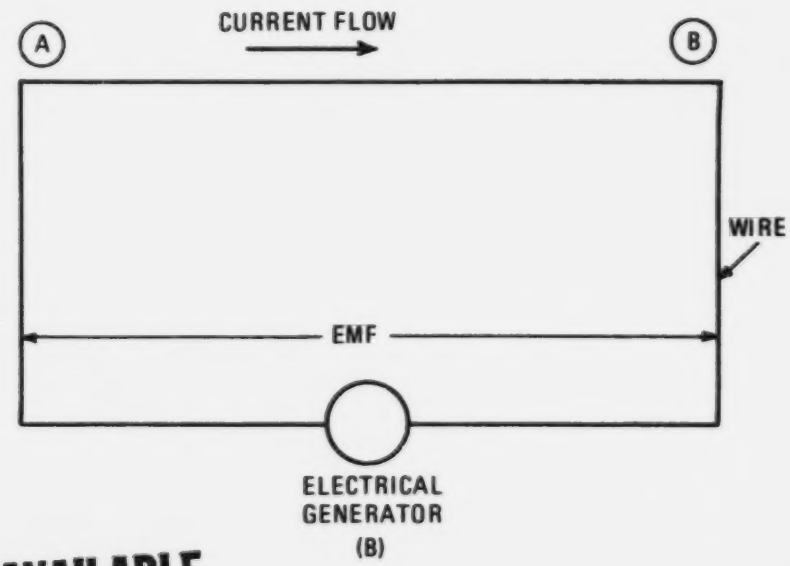


FIG. 4-4B



BEST DOCUMENT AVAILABLE

Figure 4-5 shows a closed loop of pipe filled with water. Water is circulated through the pipe by a pump. As water flows through the system, friction created by the pipe walls and restrictions in the pipe offer resistance to the flow of water. If the pump is turned off, water flow through the system stops because of this resistance. However, when it is operating, the pump provides enough pressure to offset the pipe's resistance and maintain water flow in the system.

Flow of electricity in an electrical circuit is similar to the flow of water in the system shown in Figure 4-5. Motors, elements, coils and even the wire which forms the electrical circuit offer resistance to current flow, just as the pipe walls and any restrictions in a water system resist the flow of the water. In electrical terms, this factor is called resistance.

Conductors are materials through which electricity flows easily and have relatively low electrical resistance. Common conductor materials are copper, aluminum, and graphite. *Non-conductors* are materials which have so much resistance that the electricity ceases to flow altogether. Rubber, wood, and glass are nonconductors. Nonconductors are used as insulation materials to isolate electrical circuit components and connecting conductors.

Circuit Relationships

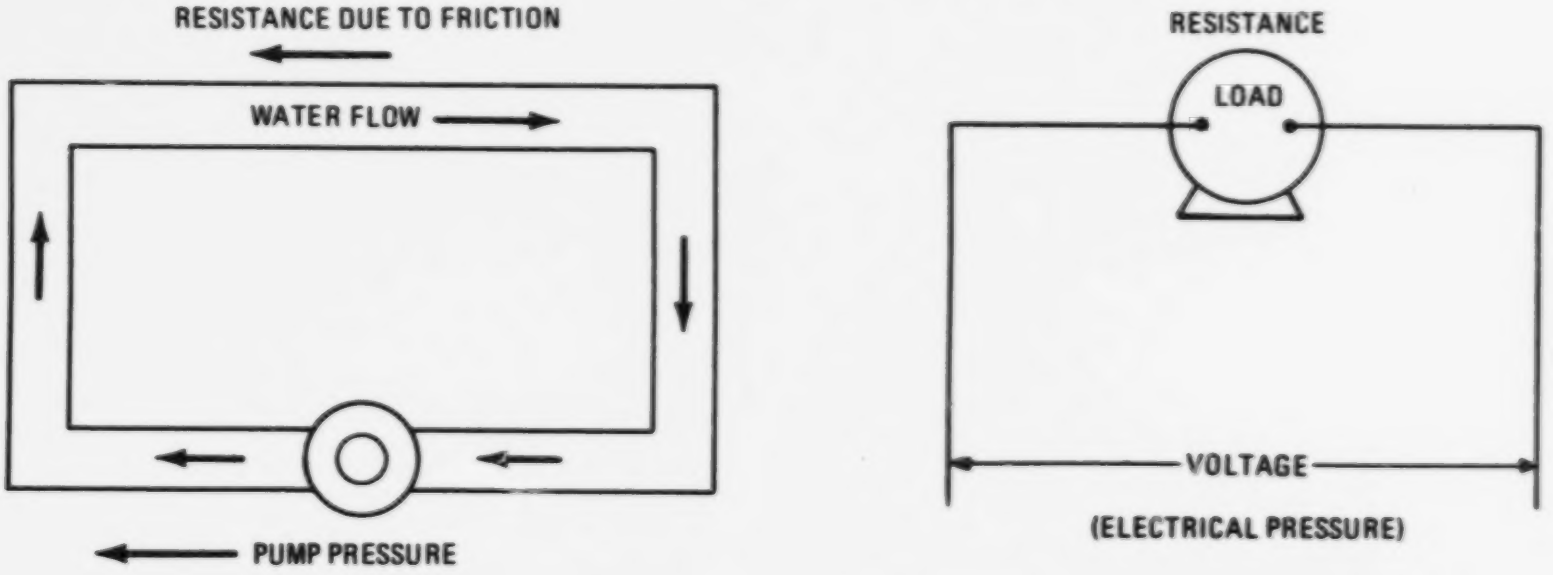
Figure 4-6 presents a water analogy to illustrate the relationships between *voltage* (E), *current* (I), and *resistance* (R) in an electrical circuit.

In Figure 4-6a the pump shown is the source of potential difference (pressure) in the closed pipe system. It is equivalent to the battery in the electrical circuit shown in Figure 4-6b. With the pump operating, water flows through the pipe system (equivalent to current flow in Figure 4-6b). The pipes (through wall friction, restrictions, etc.) offer a resistance to the water flow, just as the wiring in the electrical system offers some resistance to electrical flow. To simplify the explanation, in Figure 4-6b all of the resistance in the circuit (including that in the battery) is totaled as a single resistance, labeled R.

With a given flow rate in the water system, the pump will produce just enough potential difference (pressure) to overcome the total pipe resistance in the system for a given flow of water. In other words, the pressure increase through the pump will just equal the total pressure drop in the system. Likewise, the voltage produced by the battery will just equal the potential drop (voltage drop) through the electrical circuit for a given rate of flow.

FIG. 4-5

WATER ANALOGY IN ELECTRICAL TERMS



BEST DOCUMENT AVAILABLE

The relationships between voltage, current, and resistance in an electrical circuit are summed up by *Ohm's Law* which can be expressed *three* different ways by simple mathematical formulas.

E = voltage (in volts).
I = current (in amperes).
R = resistance (in ohms).

where $E = I \times R$

or $I = \frac{E}{R}$

or $R = \frac{E}{I}$

This states that the voltage (in volts) in a circuit is equal to the current (in amperes) times the resistance (in ohms). To illustrate its use, consider the simple circuit shown in Figure 4-6b. Assume that the resistance (R) shown is 5 ohms. We measure the current flow to be 2 amperes. What is the battery voltage?

$E = IR$
$E = 2 \times 5$
$E = 10$ volts (Answer: battery voltage = 10 volts)

The three terms shown in the formula can be rearranged to provide a second form of Ohm's Law.

$$I = \frac{E}{R}$$

That is, current flow (in amperes) is equal to the voltage (in volts) divided by the resistance (in ohms).

Ohm's Law also can be expressed in a third way:

$$R = \frac{E}{I}$$

That is, the total resistance (in ohms) is equal to the voltage (in volts) divided by the current (in amperes).

FIG. 4-6A

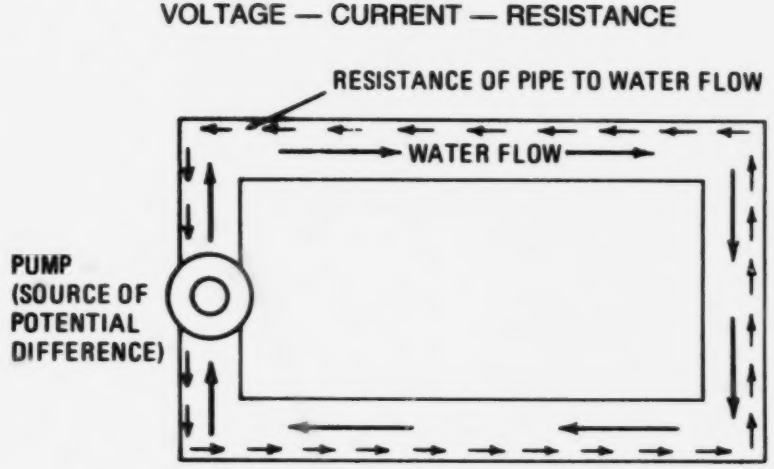
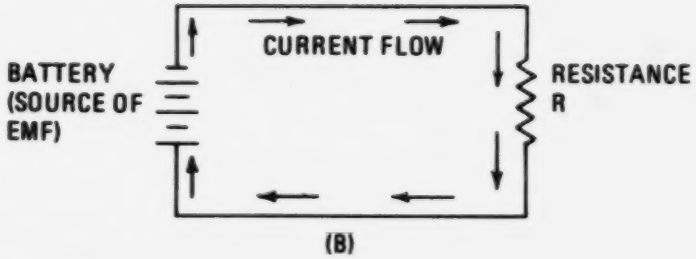


FIG. 4-6B



Ohm's Law has been discussed in terms of the entire electrical circuit, where all of the individual resistances have been added together into one single resistance total. In actual practice more than one electrical device generally operates in a circuit, and each has its own individual resistance. In order to use Ohm's Law for the entire circuit, all of the resistances in the system must be totaled into a single resistance.

On the other hand, Ohm's Law can be used to determine any one of the three fundamental electrical characteristics (E, I, or R) for any *single* element in the circuit if the other two quantities are known.

BEST DOCUMENT AVAILABLE

Voltage

The unit used for the measurement of voltage is called the *volt*. Voltages common in heating appliance control systems are classified as millivoltage, low and high. Millivoltage is generally expressed in thousandths of a volt, or millivolts. Some solid state circuits, as well as simple thermocouples and thermopiles, operate in the millivolt range.

Low voltage is usually between one and thirty volts. This is a very practical and safe voltage range. Most automobile electrical systems operate at 12 volts; many climate control systems operate on 24 volts.

High voltages are normally above 30 volts. The most common high voltage is 120 volts, which is the normal voltage used in homes and by industry in the United States. However, many domestic and commercial applications require 240 volts. Distribution lines servicing residential areas often operate at 1,150 volts or more. This voltage is reduced to 480, 240, and/or 120 volts by transformers at the utility pole or transformer pads within the building.

Current

Current is a measure of the number or rate of electrons flowing past a certain point in one second. Current is normally measured in *amperes* (amps). Typical household electrical circuits have a capacity of 15 or 30 amps. Automotive electrical circuits commonly are designed for 1 to 20 amps. Fan and pump motors found in heating appliances normally average 4 to 6 amps. Control circuits operate at much lower current levels. Current in these circuits is normally measured in fractions of one amp (i.e., .2 amp) or in milliamperes (thousandths of an amp).

Resistance

Resistance in a circuit or electrical component is measured in *ohms*. Resistance may be as little as one thousandth of an ohm (milliohm) for a piece of wire, or many thousands of ohms for electronic circuits. Widely varying resistances are often designed into circuits to control the flow of electricity.

ELECTRICAL SUPPLY SOURCES

Sources of electricity use some form of energy to create a potential difference (voltage) in an electrical circuit. This energy may be mechanical, chemical, heat, or energy in some other form. *Storage batteries* convert chemical energy to electromotive force (emf). Mechanical generators convert rotating mechanical movement into electricity. Thermoelectric devices convert heat energy directly into electricity. Piezoelectric devices convert force, or pressure into electricity.

The Chemical Cell or Battery

A chemical cell (or battery) converts chemical energy into electrical energy to provide a voltage in an electrical circuit.

A common type of chemical cell is the lead-acid cell (See Figure 4-7), which is enclosed in a hard rubber or plastic case, containing a solution of sulphuric acid and water. This solution is referred to as the *electrolyte*. Plates of sponge lead and lead peroxide (called the electrodes) are immersed in the electrolyte.

The chemical reaction of the electrolyte on the metal electrodes causes electrons to be drawn from the lead peroxide electrode, leaving it positively charged (a deficiency of electrons). These electrons are deposited on the spongy lead electrode, so that it has an excess of electrons and is negatively charged, relative to the other electrode. Thus, a potential difference (emf) has been established between the two electrodes.

If an electrical circuit, consisting of a wire, switch, and light bulb is connected to the battery electrodes, as shown in Figure 4-7, with the switch open, the electrical path through the circuit is broken and no electricity flows through it. However, when the switch is closed, the electrical path is completed. Free electrons (electricity) flow from the negatively charged spongy lead electrode to the positively charged lead peroxide electrode, then through the external circuit, just as was described earlier in relation to Figure 4-2. The lamp will glow, indicating that electricity is flowing.

Chemical reactions between the electrolyte and electrodes continue to take place. These reactions constantly replenish the supply of free electrons to the negative electrode and remove them from the positive electrode, so electricity continues to flow through the external circuit. Note that the free electrons in this case only travel in one direction, from the negative to the positive electrode. This type of electricity is known as *direct current* (DC).

Electricity cannot be drawn indefinitely from a cell. Eventually the cell will run down. During the chemical action in the lead-acid cell, the active electrode materials are gradually changed to lead sulphate. If electricity is drawn from the cell until all the spongy lead and lead peroxide are changed to lead sulphate, the cell will be completely dead, and will no longer supply electromotive force. Before this situation occurs, however, it is often possible to recharge the cell.

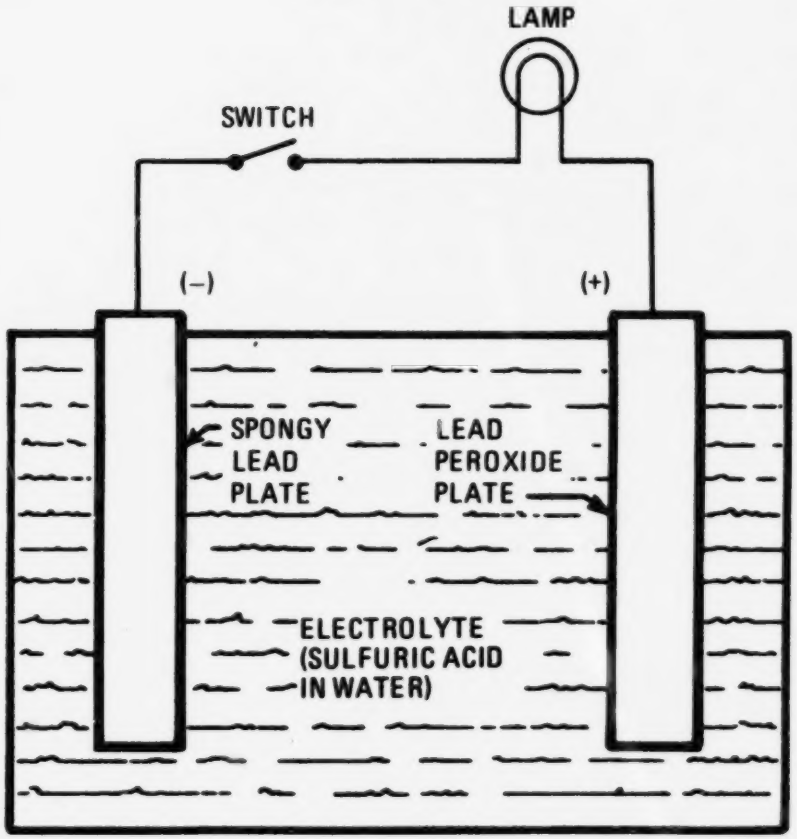
Mechanical Generators

Most of our so-called "house current" is produced by mechanically operated devices, commonly referred to as electrical generators or simply as generators.

BEST DOCUMENT AVAILABLE

FIG. 4-7

LEAD-ACID CELL



The development of the electrical generator was made possible by a simple discovery. A voltage is produced in a wire whenever the wire is moved through a magnetic field. Magnets were found to have two distinct ends, or poles. These ends or poles are commonly called North or South. The unlike poles of two magnets were found to attract each other, while like poles repelled each other. Invisible lines of magnetic force were found to exist between unlike poles. By moving a wire through this magnetic field, a voltage was produced in the wire. It was also found that the same effect was obtained by holding the wire stationary and moving the two magnets.

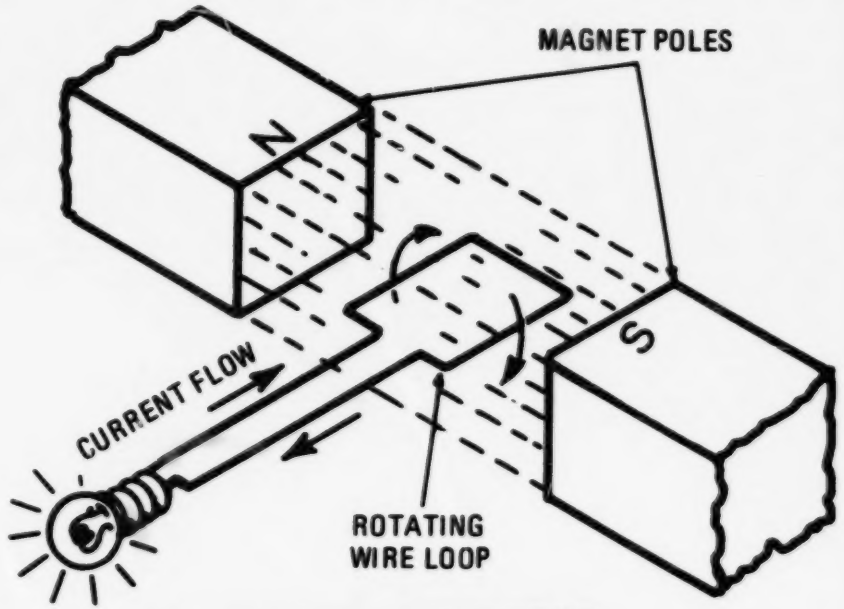
When a loop of wire is rotated in a gap between poles (see Figure 4-8), voltage is produced which tends to make electricity flow in one direction in the loop during one half of the revolution and in the opposite direction during the second half of the revolution. When wires of the loop are traveling parallel to the magnetic lines of force (across the top and bottom of the gap) no voltage is produced in the loop, (see Figure 4-9). When the loop is closed, a circuit is complete allowing electric current to flow. The alternating building up of voltage, dropping to zero and then building in the opposite direction creates what we call alternating current (AC) electricity.

The simple generator described above, using a single wire loop, will generate only a small voltage. Voltage output is increased by using more wire loops and a stronger magnet with more concentrated lines of magnetic force. In commercial generators a great many loops are wound around an iron core which increases and concentrates the magnetic field. Together these loops and core form what is called an *armature*. The electrical output of the generator is collected by brushes riding on *collector rings* attached to the ends of the rotating loops.

The number of times per second which the electrical output of an AC generator reverses direction (or polarity) is known as the electrical *frequency*. This frequency depends on the number of pairs of magnetic

FIG. 4-8

OPERATION OF ELECTRIC GENERATOR



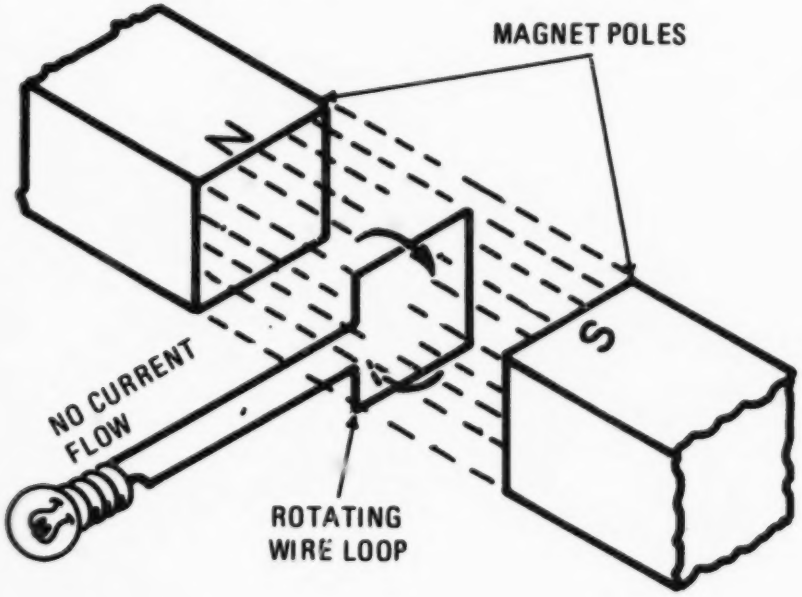
BEST DOCUMENT AVAILABLE

poles used in the generator and the rotational speed of the armature. With a single pair of poles, a generator rotating at 3600 revolutions per minute (rpm) would produce 60 cycles per second (60 *Hertz*, Hz) AC electricity. This is the frequency used in the United States. In Europe and elsewhere, 50 cycles AC electricity is most commonly used. Electrical devices must be operated at their design frequency. For example, an electric clock designed for 60 cycles operation would run slow if supplied with 50 cycles AC electricity. In many instances, overheating will result if the wrong frequency electricity is used.

The generator armature is rotated by some type of external driver to produce electricity. This driver may be, for example, a steam engine or turbine, an internal combustion engine, or in hydroelectric generators (a water-driven turbine). The generator converts only a portion of the mechanical energy supplied by these drivers into electrical energy.

FIG. 4-9

OPERATION OF ELECTRIC GENERATOR

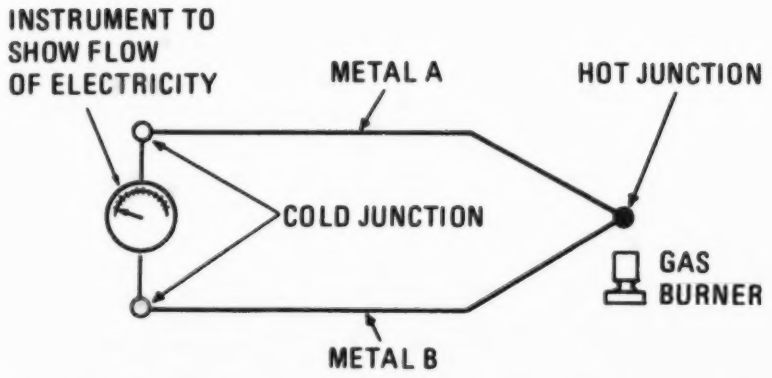


Thermoelectric Sources

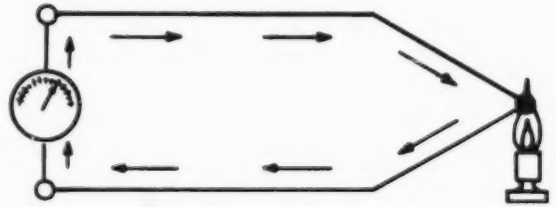
In 1822, Thomas J. Seebeck (1770-1831) discovered a principle called thermoelectricity. Basically, Seebeck joined two wires or strips of different metals together at one end. When the joined end was heated, a voltage was

FIG. 4-10

THERMOELECTRIC EFFECT



A. HOT JUNCTION NOT HEATED–NO ELECTRICITY PRODUCED



B. HOT JUNCTION HEATED–ELECTRICITY FLOWS IN CIRCUIT

produced across the open ends. A single pair of wires used for this purpose is called a *thermocouple*. Figure 4-10 illustrates the thermoelectric effect in a heated thermocouple.

The junction of the two dissimilar wires in a thermocouple which is heated to produce electricity is called the *hot junction*. The other end of the two thermocouple wires is called the *cold junction*. In a thermocouple used in a gas appliance, the cold junction usually is located only a few inches from the hot junction, and conductors are attached to the cold junction leads to carry current to a load (the electromagnet or safety).

The quantity of voltage produced thermoelectrically depends on the two materials used in the thermocouple, and on the temperature difference

BEST DOCUMENT AVAILABLE

between the hot and cold junctions. The greater the temperature difference, the larger the voltage produced, and vice-versa. Many times a pilot flame heats the cold junction of a thermocouple. If this occurs, the millivolts generated will become insufficient to energize the safety electromagnet. As a result, pilot outage will occur.

The voltage produced by a single thermocouple usually is very small and is measured in millivolts. However, this device is used for at least two very practical purposes in the gas industry.

First, a thermocouple can be used as a very sensitive temperature measuring device. The temperature at which a pair of different metals generate a specific voltage can be used to indicate the voltage/temperature relationship. The thermocouple hot junction can be placed in a fluid or connected to a surface that is to have its temperature measured. The voltage produced can be measured with a millivolt meter. The temperature of the fluid (water, air, etc.) or surface is then found in an appropriate table which cross references the voltage produced with the temperature. This type of device is referred to as a pyrometer. The gas industry also utilizes thermocouples in gas appliance controls, such as in *automatic pilot safety devices* (see Figure 4-11). The hot junction of the modern thermocouple is

FIG. 4-11

AUTOMATIC PILOT SAFETY DEVICE

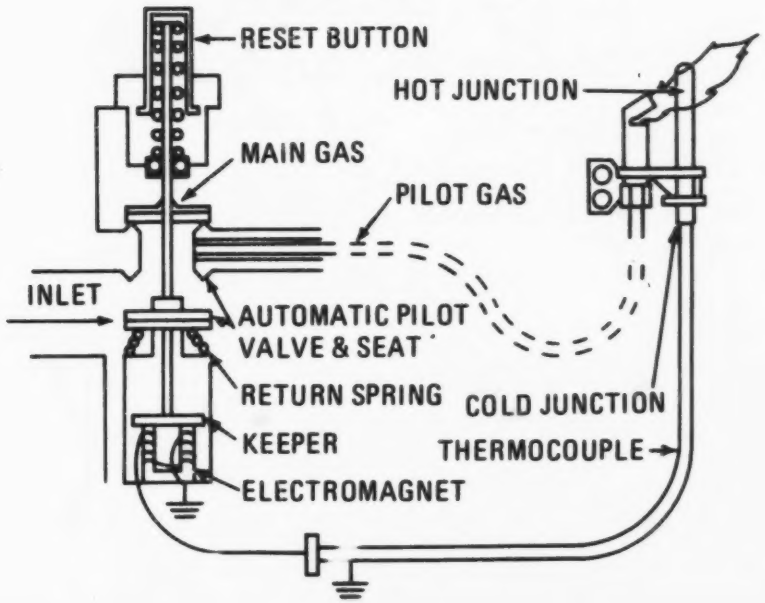
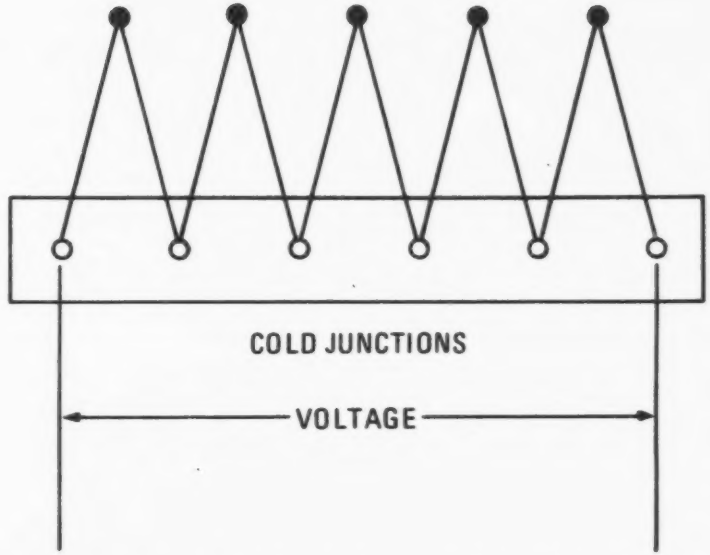


FIG. 4-12

THERMOPILE



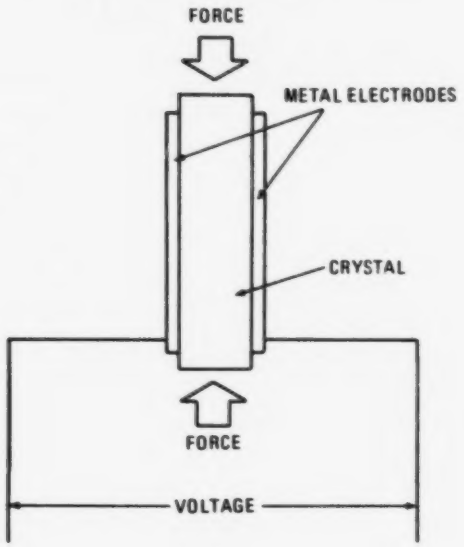
heated by a pilot flame. The electrical output of a single modern thermocouple is quite small (25-30 mV). However, this output is sufficient to produce a current flow through the circuit. An electromagnetic field is produced as this current flows through the wire. This wire can be wrapped around a metal core, creating a small electromagnet. This electromagnet will hold open an automatic pilot valve (opened manually by pressing a metal part of the valve against the electromagnet) as long as the pilot flame heats the hot junction adequately. If the pilot flame is extinguished, the hot junction of the thermocouple cools. At this point, the voltage produced by the thermocouple decreases, the electromagnet becomes de-energized, and the spring-loaded automatic pilot valve closes. The gas supply to the appliance is then shut off.

Thermoelectric voltage output can be substantially increased by combining a number of thermocouples in a single device, called a *thermopile*, (see Figure 4-12). The increased voltage can be used to create a more powerful electromagnet than with a single thermocouple. Automatic gas valves can be powered by a thermopile and not require AC voltage from the house circuit. Thermocouples and thermopiles will be discussed further in later sections.

BEST DOCUMENT AVAILABLE

FIG. 4-13

PIEZOELECTRIC EFFECT



Piezoelectric Sources

If certain materials, such as quartz and Rochelle crystals or barium titanate, are compressed in a certain direction, electrons in the material shift, creating a voltage across two surfaces of the material, (see Figure 4-13). This is called the piezoelectric effect and substances which exhibit it are called piezoelectric materials. The amount of voltage created depends on the rate of change and quantity of pressure applied. A voltage is not generated by a steady pressure on the material, but rather by a rapid squeezing or striking. Higher voltages are generated by applying greater pressures to the crystal.

Piezoelectric materials have been used to provide manual spark ignition, such as in camping equipment, and have been proposed for the same use in gas ranges, water heaters, and heaters. At this time, however, their use in gas appliances is limited to applications using manual ignitions.

TRANSFORMERS

The transformer is a device which takes electricity at one voltage and reduces it (step-down) or raises it (step-up) to a different voltage. Figure 4-14 illustrates a simple step-down transformer.

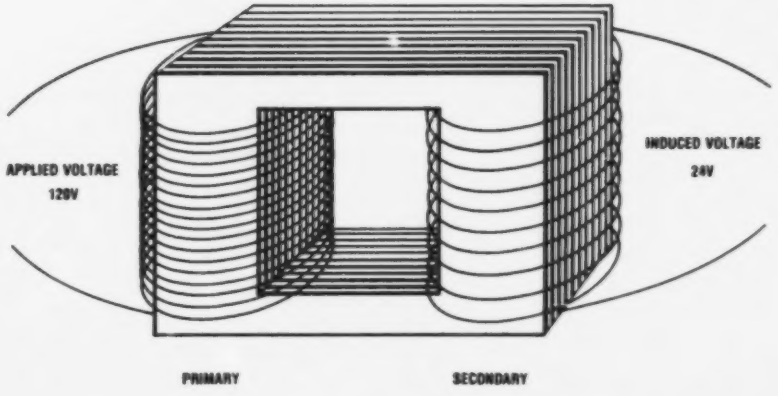
The transformer shown consists of two coils of wire wound around a soft iron core. The primary winding or first stage has more turns of wire than the secondary or second stage winding. Recall that a magnetic field surrounds a current carrying wire. When an AC voltage is applied to the primary winding, current fluctuates between zero and some maximum value. As a result of this current fluctuation, the magnetic field around the primary winding builds up and collapses with each current cycle. The lines of magnetic force cut across the turns in the secondary winding, forcing electrons to flow in the secondary winding. The secondary voltage is *induced* voltage.

Voltage output depends on the number of turns in each coil. The ratio of input and output voltage will be equal to the ratio of the number of turns in the primary and secondary windings. For example, if 120 volts are applied to a primary winding with 50 turns, the output from a secondary winding with 10 turns will be $(10/50) \times 120 = 24$ volts. Most transformers have primary and secondary windings wrapped around an iron core. This arrangement minimizes losses by concentrating the magnetic field within the iron core.

Transformers are widely used to reduce 120 volts to 24 volts. The 24 volt supply is then used as a power source for thermostats, controlling relays, gas valves, or other heating control devices. The main advantages of 24 volt circuits are the safety of their installation and overall ease of servicing the system's components.

FIG. 4-14

STEP-DOWN TRANSFORMER



BEST DOCUMENT AVAILABLE

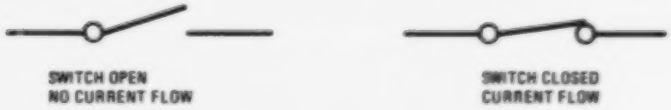
Transformers are rated by the power output of the secondary winding in terms of volts/amps or VA. Transformers must be capable of producing maximum power for the circuit on which they are installed. For example, if a 24 volt circuit draws 1.5 amps, the VA rating of the transformer should be *at least* 36 (24X1.5). In practical application, a 40VA-24 Volt transformer would be used in this application.

ELECTRICAL SWITCHING

A switch is a device used to open or close an electrical circuit. It is placed in a circuit and its poles (or terminals) are connected to the wiring on either side. With the switch in an open position, the electrical path is broken and no current flows. When the switch is closed, the electrical path through the switch and wiring is completed and current can flow in the circuit.

FIG. 4-15

SINGLE POLE — SINGLE THROW SWITCH



SINGLE POLE - SINGLE THROW SWITCH (SPST)

Normally Open and Normally Closed Switches

In addition to specifying the number of poles and throws, and the means used to actuate them, switches may also be designated as either *normally open or normally closed* (see Figure 4-15).

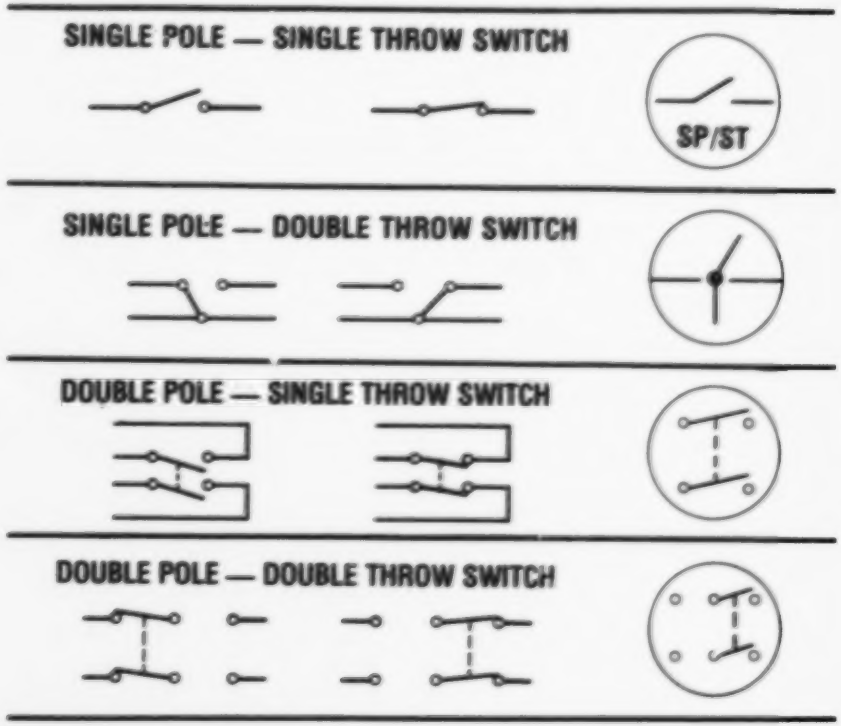
The standard method of designating switches is in a position with *no operating force applied*. Thus, a switch in the open position with no actuating force applied is referred to as normally open. A switch in the closed position, with no actuating force applied is referred to as normally closed. The symbol for normally closed switches is NC; for normally open switches is NO. For switches that may be in either NC or NO positions with no activating force applied, a clarifying note may be necessary in a circuit diagram to explain the point at which the switch functions.

Poles and Throws

There are many different types of switches. Some may control current flow in only one circuit; others may control flow in several circuits. The number of circuits controlled by the switch depends upon its number of *poles* and *throws* (see Figure 4-16).

FIG. 4-16

BASIC SWITCHING


SINGLE POLE — SINGLE THROW SWITCH
SP/ST
SINGLE POLE — DOUBLE THROW SWITCH
DOUBLE POLE — SINGLE THROW SWITCH
DOUBLE POLE — DOUBLE THROW SWITCH

Switches which are designed to control a *single circuit* are called single pole/single throw or SP/ST switches. The SP/ST switch may have normally open contacts and close when activated or it may have normally closed contacts and open when activated.

Switches which are designed to control *two circuits*, at *different times*, from the *same* common source are called single pole/double throw or SP/DT switches.

Switches which are designed to control *two circuits*, at the *same time*, from *different* sources are called double pole/single throw or DP/ST switches.

BEST DOCUMENT AVAILABLE

And finally, switches which are designed to control *two circuits*, at *different* times, from *different* sources are called double pole/double throw or DP/DT switches.

Switch Actuation

A switch may also be classified according to the way it is actuated (opened and closed). In general terms, a switch may be actuated: manually, mechanically, by temperature, by pressure, or electromagnetically.

Manual switches are actuated by hand. A home light switch, a pushbutton switch, or a toggle switch are examples of this type.

With a mechanically actuated switch, some mechanical force is applied to open or close the switch. A range oven or clothes dryer door switch is actuated by the door pressing against a spring loaded pushbutton which closes the switch when the door is closed. The contacts of this switch are either forced together or apart (depending on its function and arrangement).

Electric room thermostats, limit controls, warp switches, and some types of automatic pilot devices, to mention only a few, are devices using changes in temperature to actuate switches. Most room thermostats, limit controls, and warp switches use bimetals. Some types of thermostats and automatic pilot devices use heat sensitive diastats to provide the force or movement needed to actuate a switch.

Pressure from expanding liquid or gas is also used to actuate switches. For example, pressure switches may contain a pressure-sensitive diaphragm which moves to close or open switch contacts, or a bellows which expands or contracts in response to pressure variations to actuate the switch.

Relays are devices which electromagnetically actuate a switch. This type of device employs the principle that electricity flowing in a coil sets up a magnetic field in a metal core (electromagnet). When electricity is applied to the relay coil, the electromagnet attracts a movable armature which is attached to one of the two switch contacts, thus opening or closing the switch (depending on its arrangement). When electricity to the relay coil is shut off, the electromagnet is de-energized. The movable armature then returns to its original position by spring action, reversing the switch position. Relays allow for the control of a high current or high voltage circuit with a low voltage-low current circuit. For example, many space heating appliances use a 24 volt relay in the low voltage thermostat circuit to control a 120 volt blower motor.

ELECTRICAL RESISTIVE LOADS

Power is the rate of doing work or the rate at which energy is transferred in some process or device. The basic unit of electrical power is the watt.

Power consumed by various electrical devices is expressed in watts. For example, light bulbs are rated as 60 watt, 100 watt, etc., based on the rate at which they consume electrical energy.

Because the watt is a measure of *rate*, we can multiply watts by time to determine the quantity of work performed or energy consumed. A 100 watt light bulb operating for 10 hours consumes $100 \times 10 = 1{,}000$ watt-hours or 1 *kilowatt hour*. One kilowatt hour is equivalent to 3,413 Btu's.

Whenever an electric current flows through a device which has electrical resistance, heat is generated in the device. This creation of heat can be likened to that of friction. All materials have some electrical resistance, some more than others. The electrically generated heat in a resistive device depends on the level of current flow (amperes) and on the amount of resistance (ohms). The higher the current flow the greater will be the amount of heat generated. The resulting temperature of the device will depend on the rate at which it can dissipate this heat, which in turn depends primarily on its size (surface area) and the temperature around it. The operation of some electrical devices are based on this heat actuation principle.

For example, the electrical strip heater and electric toaster use resistive elements to produce heat. A resistive heater can also be used to heat a bimetal element to electrically control a switch.

Some gas appliances (ranges, dryers) are equipped with electrical *ignitors* to light the gas at the burners. Frequently, these ignitors are a high resistance (Nicrome) wire or a ceramic (Carborundum) body. When an electric current flows to the ignitor it generates heat until its glowing surface is hot enough to ignite gas. This type of ignitor is commonly called a "glow bar." The wire-type (usually in the form of a small coil) normally operates at relatively low voltages (such as 2 volts AC), provided by a step-down transformer. This type of ignitor is commonly called a "glow coil."

With a variable resistor, resistance may be varied over a range of values. There are several devices which do this, but the most common one is called a *rheostat* and is shown in Figure 4-17. The resistance value of the rheostat depends on the location of the movable contact arm. As the arm is moved from A to C, a greater length of the resistor element is exposed to the circuit and the resistance increases. With a given voltage source and load, the current (amps) in the circuit decreases as the resistance goes up.

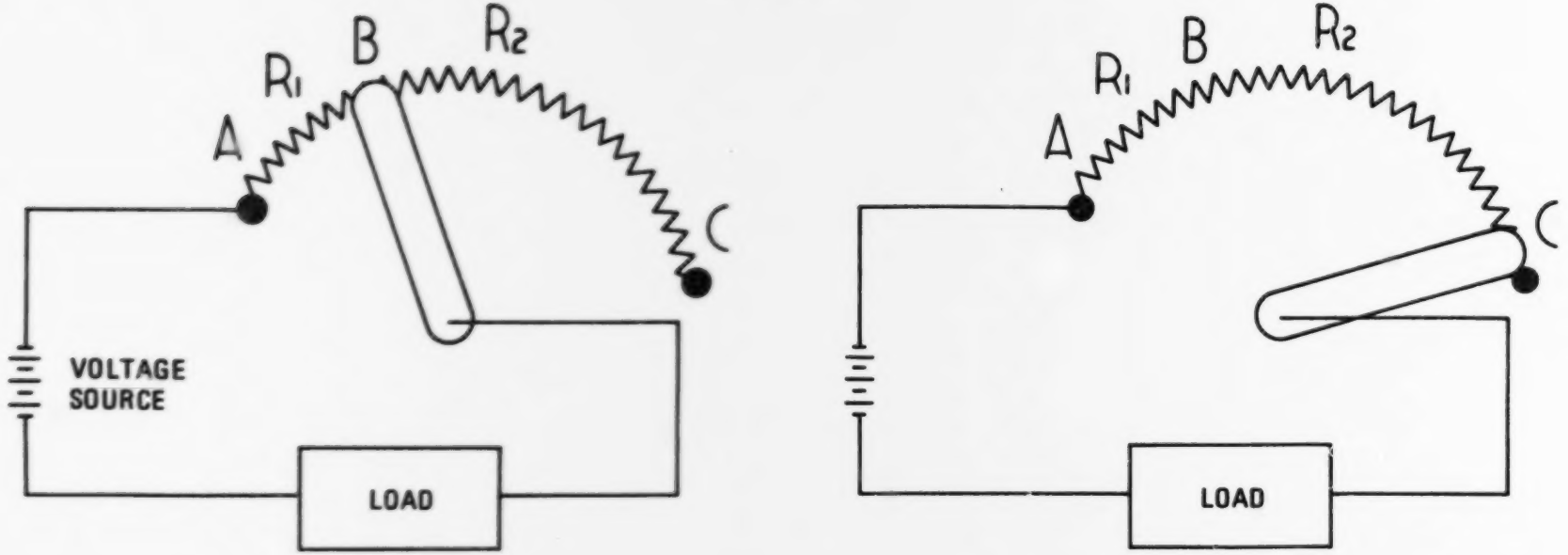
ELECTROMAGNETIC LOADS

Electrical current flowing through a wire creates a magnetic field around the wire. This magnetic field can be concentrated if the wire is coiled around an iron core. The magnetic force can be controlled by switching the electricity on and off.

BEST DOCUMENT AVAILABLE

FIG. 4-17

RHEOSTAT



Electromagnets are the basic element in a wide variety of operating and control devices. Electromagnetic switches (relays) were discussed earlier. Electromagnets are also used to actuate clutches, brakes, and other devices.

Electromagnets called *solenoids* (see Figure 4-18) are often used in automatic gas control valves. A rod, connected to the valve disc, is attracted by the electromagnet when it is activated, opening the valve. When the electromagnet is de-activated, a tension spring forces the rod and valve disc back to their original position, thus causing the valve to close. The solenoid is normally activated by a type of switch such as a thermostat.

The electric *motor* is a device which converts electrical energy into mechanical energy. That is, its function is just the opposite of an electrical generator, which converts mechanical energy into electricity. Electric motors are commonly used in gas appliances to drive circulating air blowers and water pumps.

Since virtually all motors which are used in gas appliances are AC motors, our coverage will be limited to these. There are a variety of ways in which motors are constructed (wound) depending on the desired operating features.

Appliance motors used on furnace blowers, pumps, and refrigerator compressors are usually induction motors. These motors operate on the principle of induced electromagnetic effects by using two out-of-phase currents to produce a rotating magnetic field.

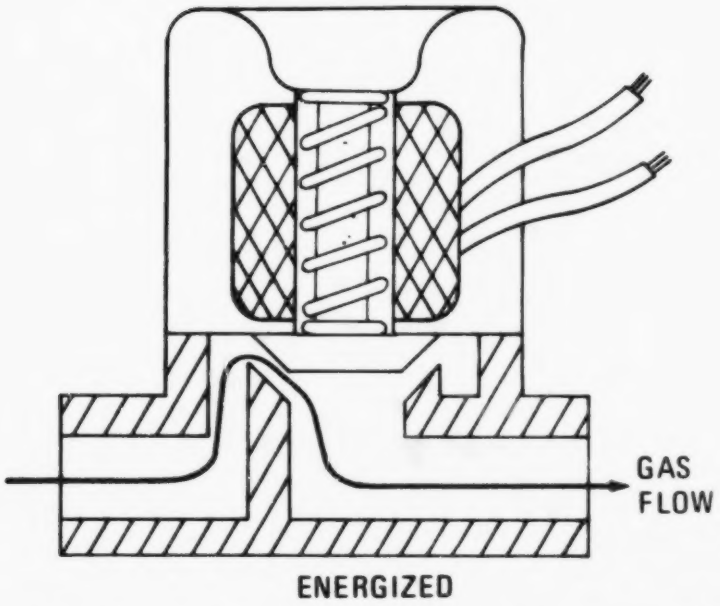
These out-of-phase currents can be produced by either inductance or capacitance in the motor circuit. In some designs, a capacitor is used only for starting, and as the motor reaches full speed, a centrifugal switch removes the capacitor and start winding from the circuit.

Another variation of the induction motor is the shaded-pole motor. This is the simplest AC motor design since it uses no capacitors, starting windings, or centrifugal switches however, power output is low. These motors

BEST DOCUMENT AVAILABLE

FIG. 4-18

SOLENOID VALVE



are used frequently on appliances where high torque or power is not required.

ELECTRICAL CIRCUITS

There are two basic ways to arrange components in an electrical circuit: in *series* or in *parallel*. In a series circuit, there is only one path for current. All components are connected so that the electric current must pass through each component in sequence. In parallel circuits, however, more than one path is available for current flow. In addition, the electrical circuit may have a mixture of these two arrangements, with some elements in series and others in parallel. In the following paragraphs, pure series or pure parallel circuits will be considered separately to simplify the explanations.

Series Circuits

A water analogy of the series circuit is shown in Figure 4-19a. A pump is supplying potential difference (pressure) to produce a flow of water in the system. In this case, however, the piping system is divided into four sections (AB, BC, CD, and DE), which are in series. That is, there is only one continuous path for water flow. As water flows through the system, friction losses, etc., create a pressure drop in each section of pipe.

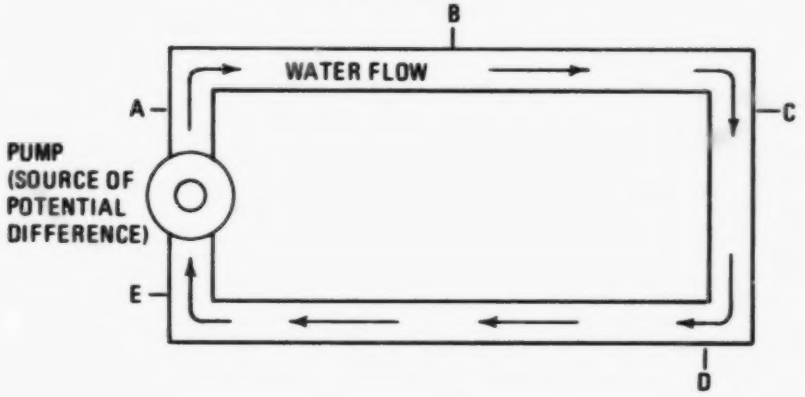
The water flow rate through the entire system must be the same through each section. A pressure drop due to resistance to flow caused by friction will take place in section AB and likewise in section BC. Then, the total pressure drop from A to C must equal the sum of the pressure drops from A to B and from B to C. The same holds true around the entire system. The total pressure drop through the system equals the sum of all the individual pressure drops in series in the system. Furthermore, the total pressure drop in the system must equal the potential difference (pressure) provided by the source (pump).

The equivalent series electrical circuit is shown in Figure 4-19b. The pump is now a battery producing a voltage in the system, and four separate resistances (R_1, R_2, R_3, and R_4) take the place of the four sections of pipe.

WATER ANALOGY

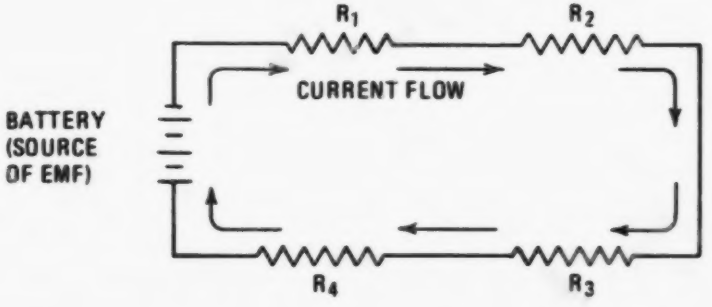
SERIES ELECTRICAL CIRCUIT

FIG. 4-19A



(A)

FIG. 4-19B



(B)

BEST DOCUMENT AVAILABLE

Keeping the water flow analogy in mind, the following are rules which apply to all *series* circuits:

1. The current through the entire circuit, is the same as the current through any single load.

2. The sum of all of the voltage drops across the individual resistances is equal to the applied voltage.

3. The total resistance is equal to the sum of all individual resistances.

In short, the series circuit shown in Figure 4-19b can be considered to be a circuit with one resistance (such as that shown in Figure 4-6). $R_T = R_1 + R_2 + R_3 + R_4$. Therefore, Ohm's law can be applied to the entire circuit. Also, the voltage drop through each individual resistance can be calculated from the equation, $E = IR$, using the current flow in the circuit, and the appropriate resistance (R_1, R_2, R_3, R_4).

For example, suppose that the source shown in Figure 4-19b supplies 30 volts to the circuit and the resistances shown are: $R_1 = 2$ ohms, $R_2 = 3$ ohms, $R_3 = 4$ ohms, and $R_4 = 6$ ohms. The total resistance (R_T) of the series circuit, which equals the sum of the individual resistances in the circuit, is 15 ohms (2 + 3 + 4 + 6 = 15). By use of the equation defining Ohm's law, the current flow in the series circuit shown in Figure 4-b is:

$$I = \frac{E}{R}$$

$$I = \frac{30}{15}$$

$$I = 2 \text{ amperes}$$

This amount of flow takes place through each of the resistances in series, so that the voltage drop through each resistance can be calculated by the equation defining Ohm's law:

$$E = I \times R$$

$$E_1 = I \times R_1 = 2 \times 2 = 4 \text{ volts}$$

$$E_2 = I \times R_2 = 2 \times 3 = 6 \text{ volts}$$

$$E_3 = I \times R_3 = 2 \times 4 = 8 \text{ volts}$$

$$E_4 = I \times R_4 = 2 \times 6 = 12 \text{ volts}$$

Note again that the series of voltage drops through these individual resistances equals the voltage output (30 volts) of the source (4 + 6 + 8 + 12 = 30).

Parallel Circuits

In a parallel electrical circuit, components are connected so that more than one path is provided for current flow within the circuit. Figure 4-20 illustrates a parallel circuit and a corresponding water analogy.

Figure 4-20a represents a parallel water flow system in which two paths are provided for water flow (through pipe BE and pipe CD). The equivalent parallel electrical circuit in Figure 4-20b substitutes resistance R_1 for the resistance of pipe BE and R_2 for pipe CD.

Assume that resistance to water flow in pipes ABC and DEF is negligible, just as resistances of the conductors connecting the battery to R_1 and R_2 in Figure 4-20b are negligible. Then, with no pressure drop from A to B or from B to C, the pressures at B and C must be the same; likewise the pressures at D and E are the same if no pressure drop occurs from D to F. The pressure drops across BE and CD must be equal.

Let Q be the total water flow rate from the pump into the system and returning to the pump. Part of this water flow rate (Q_1) passes through BE and part (Q_2) through CD; therefore, $Q = Q_1 + Q_2$. The relative amounts of water flow thorugh BE and CD will depend on the relative resistances of these pipes (friction losses, etc.).

Keeping the water analogy in mind, the following are rules which apply to all parallel circuits:

1. The voltage across any parallel load is the same as the applied voltage.

2. The total current flow is equal to the sum of the current flow in all resistances.

The relationship of resistance R_1 and R_2 to the total resistance in the parallel circuit shown in Figure 4-20b can be expressed as $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

The most important point to remember about this equation is that the total resistance of the parallel circuit is always *less* than the smallest resistance (within a number of resistances) in parallel in the circuit. Put another way, if the voltage from the source is kept constant, more total current will flow as additional parallel resistances are placed in the circuit. In terms of the water flow analogy, if additional parallel paths for flow are added to the piping system and the potential difference (pressure) the pump supplies is kept the same, the flows through BE and CE will still be the same, and additional flow through the added pipe will allow a greater total flow in this system.

BEST DOCUMENT AVAILABLE

Consider a parallel circuit in which the source provides a voltage of 12 volts. Three resistors are placed in parallel in the circuit with $R_1 = 4$ ohms, $R_2 = 6$ ohms, and $R_3 = 12$ ohms. The total resistance of the circuit is:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

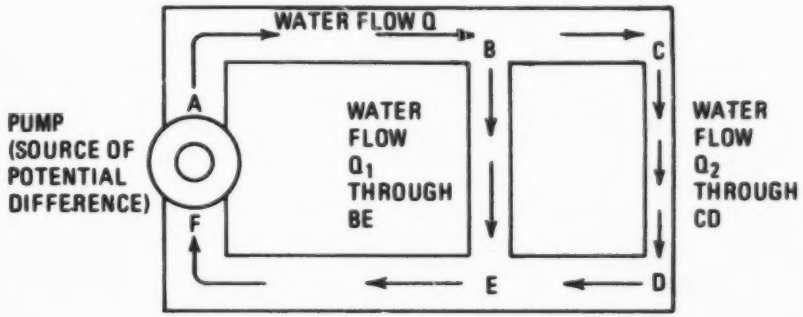
$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$$

$$\frac{1}{R_T} = \frac{3 + 2 + 1}{12} = \frac{6}{12}$$

Then: $R = \frac{12}{6} = 2$ ohms.

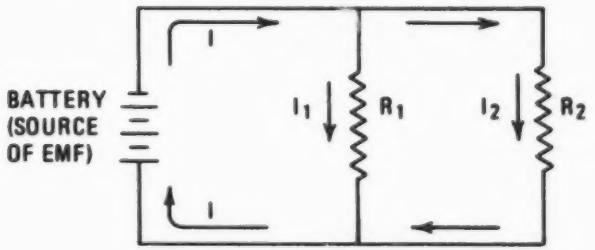
WATER ANALOGY PARALLEL ELECTRICAL CIRCUIT

FIG. 4-20A



(A)

FIG. 4-20B



(B)

Note that R is less than the smallest resistance (4 ohms) in parallel in the circuit. By Ohm's law, expressed by the equation, $I = \frac{E}{R}$:

$$I = \frac{E}{R} = \frac{12}{2} = 6 \text{ amperes}$$

$$I_1 = \frac{E}{R_1} = \frac{12}{4} = 3 \text{ amperes}$$

$$I_2 = \frac{E}{R_2} = \frac{12}{6} = 2 \text{ amperes}$$

$$I_3 = \frac{E}{R_3} = \frac{12}{12} = 1 \text{ ampere}$$

Note that the sum of the current flowing through the three resistors equals the total current flow in the circuit (1 + 2 + 3 = 6).

ELECTRICAL CIRCUIT DIAGRAMS (SCHEMATICS)

Electrical circuit diagrams are basically graphic illustrations showing all components of a circuit in relation to each other. They are roadmaps which show the path of electrical flow and are useful in understanding how a particular circuit performs its functions. They are essential for troubleshooting electrical malfunctions. Two variations of wiring diagrams are commonly used for gas appliances: *connection diagrams* and *schematic diagrams*. ANSI standards now require appliance manufacturers to supply both.

Connection Diagram

A connection diagram shows the connections of an installation or its component devices or parts. It may cover internal or external connections or both, and contains such details as are needed to make or trace the circuit connections involved. The component devices or parts are usually shown in the general arrangement in which they exist on the appliance. Figure 4-21 is a typical connection diagram of a forced air furnace. This type diagram is most valuable where the number of components and component wiring is limited. As the wiring becomes more complicated the value decreases due to the difficulty in identifying and routing individual wires.

BEST DOCUMENT AVAILABLE

Schematic Diagram

The schematic diagram uses graphic symbols to show the electrical connections and functions of an electric circuit. The schematic is used when tracing the circuit and sequence of functions. It is presented for ease of use without regard to size, shape, brand, or location of the component parts. A *ladder diagram*, now the form of schematic required by appliance standards, is usually drawn in the form of a vertical ladder (see Figure 4-22). The outer vertical lines represent the electrical supply conductors. The horizontal steps represent individual circuits with associated components. Figure 4-22 is a ladder diagram of the same circuit shown in Figure 4-21.

The schematic diagram helps isolate separate parts of the circuit, aiding in troubleshooting. For instance, consider an appliance such as a furnace in which the blower motor will not run. By isolating the motor and its circuit on the schematic, the switches that control the circuit can be located. Testing the switches and motor will pinpoint the defective part.

Component Symbols

As previously stated, schematic diagrams use symbols to represent components. Figure 4-23 shows a number of symbols used by gas space heating manufacturers. It is important to note that several different symbols may be used to represent one component. In addition, manufacturer's may use symbols which are not included in this listing.

FIG. 4-21

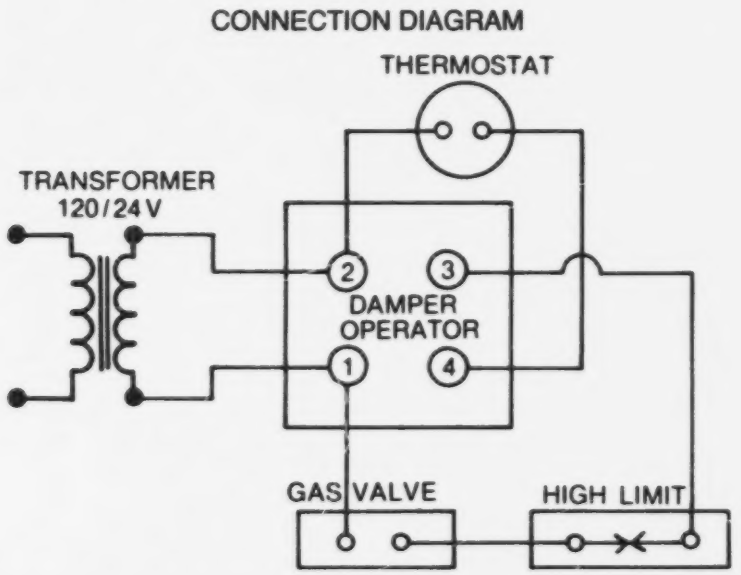
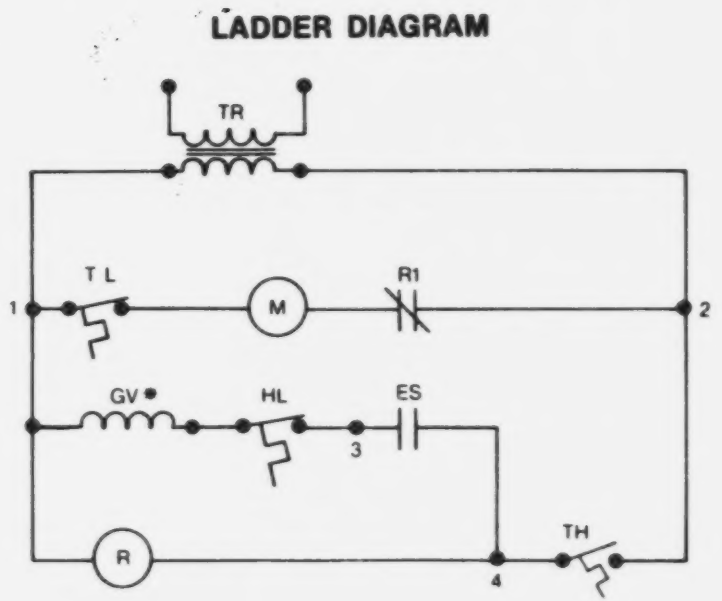


FIG. 4-22



TEST EQUIPMENT AND CIRCUIT TESTING

Circuit testing and troubleshooting can be effectively performed with relatively inexpensive test devices. The *volt-ohm meter* (VOM) is an instrument which can be used to measure voltage present in a circuit or parts of that circuit, and the resistance (and hence continuity) of circuit components. The basic volt-ohm meter is actually four instruments in one. It usually contains a switching arrangement to measure either AC or DC voltage, DC current, and resistance. More elaborate multi-meters also include a *millivoltmeter* designed to accurately measure very small DC voltages and an *ammeter* to measure the flow of current in AC circuits.

The Voltmeter

The operation of a *voltmeter* is based on two principles which have been discussed previously: (1) electricity flowing through a wire or a coil creates a magnetic field about that wire and coil, and (2) adjacent magnetic fields react on each other causing a part to move or rotate. The moving part in a voltmeter is attached to a needle which moves across a calibrated dial indicating the value or level of voltage being measured.

A common type of voltmeter is shown in Figure 4-24.

BEST DOCUMENT AVAILABLE

FIG. 4-23

SYMBOLS

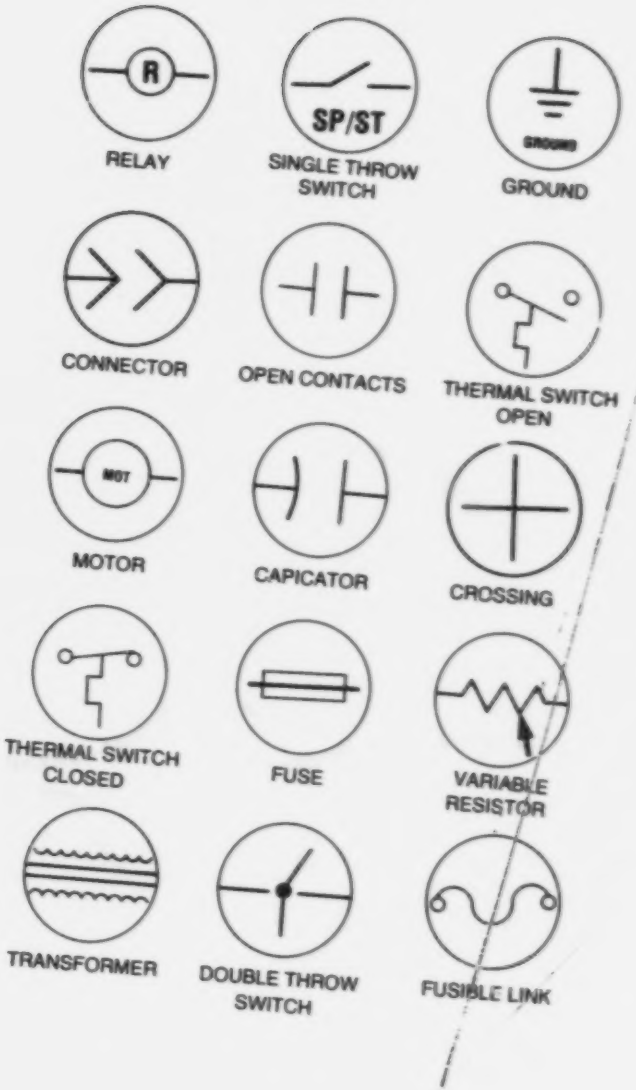
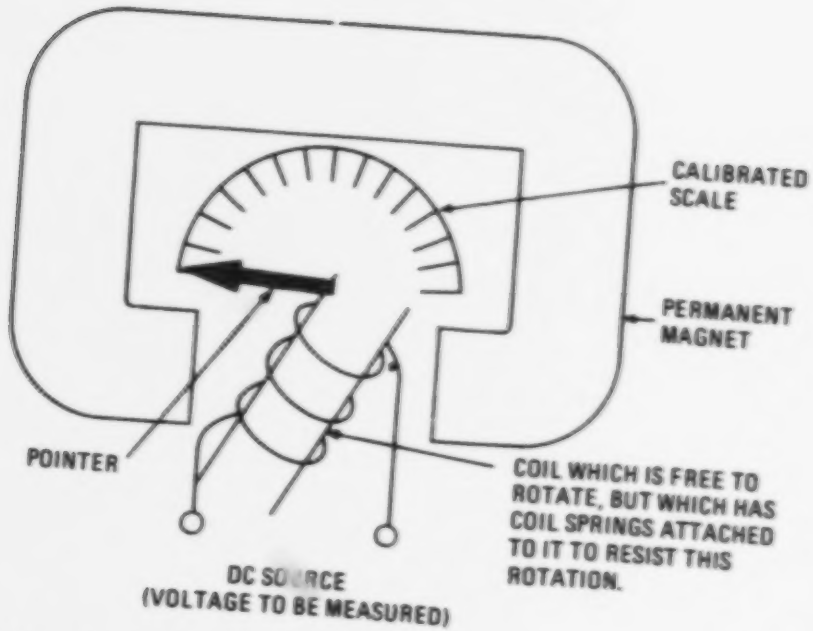


FIG. 4-24

VOLTMETER


CALIBRATED SCALE
PERMANENT MAGNET
POINTER
COIL WHICH IS FREE TO ROTATE, BUT WHICH HAS COIL SPRINGS ATTACHED TO IT TO RESIST THIS ROTATION.
DC SOURCE
(VOLTAGE TO BE MEASURED)

In Figure 4-25, a voltmeter is being used to measure the voltage drops across the entire circuit and across each resistance in the circuit. Recall that in a series circuit, the sum of all the voltage drops across components in the system is equal to the voltage of the source. Thus, a voltmeter in position V_1 would indicate 120 volts (the source voltage, or the total of the voltage drops through R_2 and R_3).

To measure the voltage drops across resistances R_2 and R_3, the voltmeter is connected as shown by V_2 and V_3, respectively. If $R_2 = R_3$, then the voltage drop across these resistances would be the same, and $V_2 = V_3 = 60$ volts ($60 + 60 = 120$).

The voltmeter range can be changed by switching to various meter settings or scales. *When measuring a voltage, the instrument should be switched to the highest scale setting for the first reading.* Then, when the voltage has been read, the scale setting can be changed to a lower range to obtain a more accurate voltage reading. This procedure is followed to prevent possible damage to the voltmeter. If the scale setting is too low for the voltage being measured, the needle will be "pegged" against the stop, which might damage the needle and/or the voltmeter.

BEST DOCUMENT AVAILABLE

The Ohmmeter

The ohmmeter is designed to measure the resistance (ohms) of a component. The ohmmeter has its own voltage source (usually a small dry cell). The ohmmeter should *never be* connected to any outside source of electricity. If it is, the ohmmeter will almost certainly be damaged.

The simple ohmmeter circuit, Figure 4-26, consists of a voltage source (small battery), a basic meter movement (R_m), a variable resistor (R_h) to zero the meter, and a fixed resistor (R_f) to limit current flow in the coil. The unknown resistance to be measured is placed between terminals A and B. With the ohmmeter needle to the right, a reading of zero ohms will appear. With the needle to the left, an infinite resistance will appear (shown by the symbol ∞).

Before measuring a resistance, leads A and B are placed together so the resistance between A and B is essentially zero ohms. If the meter does not read zero, the voltage in the meter may be incorrect. However, by adjusting with R_h (zero adjustment), the needle can be positioned so that it reads zero. When the leads are removed from each other, the meter should

FIG. 4-25

MEASUREMENT OF VOLTAGE DROP

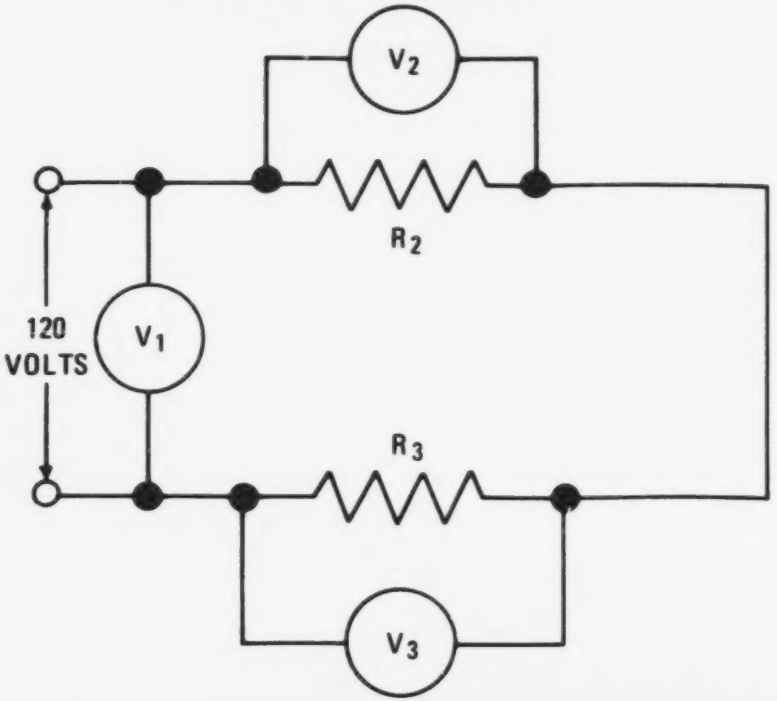
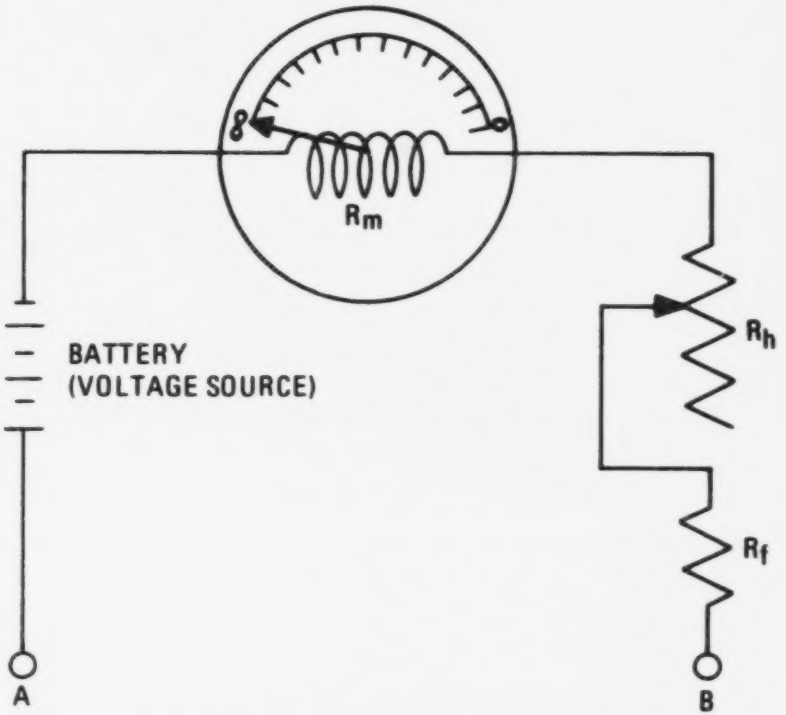


FIG. 4-26

OHMMETER CIRCUIT



indicate infinite resistance. If it does not, the infinite resistance adjustment can be adjusted (if one is provided on the meter). After the meter has been adjusted, the unknown resistance is connected between A and B and the needle indicates the resistance in ohms on the scale (somewhere between zero and infinity). *Never use an ohmmeter to check a circuit which has an external voltage applied to it.* In addition, when the resistance of an individual component is being determined, *always* isolate the component from the rest of the circuit.

The Millivoltmeter

Many gas appliances use thermoelectrically-generated DC voltage in automatic pilot systems. The millivoltmeter is used to measure these low voltages when servicing gas appliances. The DC millivoltmeter works on exactly the same principles as the DC voltmeter, but is designed specifically to measure very small DC voltages. Again, the millivoltmeter may be incorporated into a multi-meter *or* is available as an independent meter.

BEST DOCUMENT AVAILABLE

The Ammeter

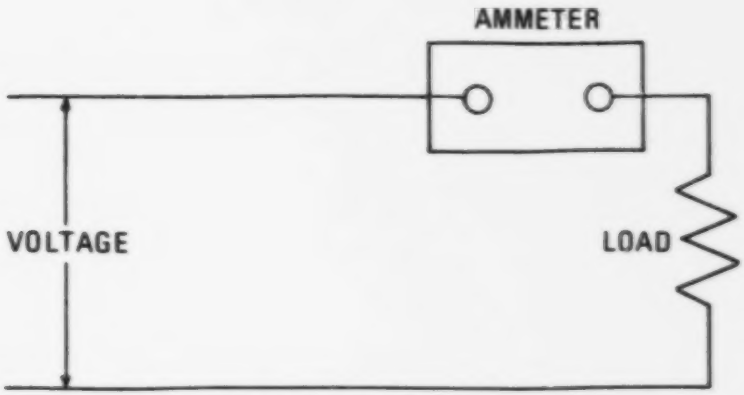
Generally, there are two types of ammeters commonly used in testing and troubleshooting gas appliances. The first type ammeter is normally incorporated into most VOM's and is used to measure only very small quantities of DC current. This type ammeter is placed in series with the circuit being measured (see Figure 4-27).

When it is necessary to measure higher quantities of AC current, a clamp-on ammeter can be used. The clamp-on ammeter needs no actual contact with wires or terminals (see Figure 4-28). It is simply clamped around a wire carrying current to be measured. Essentially, the current induces a magnetic field which is detected by the clamp and is indicated on the meter scale.

If the current flow in the circuit is extremely low, the value which the meter detects may be increased by looping the circuit wire around the clamp. For example, 10 loops causes the reading to appear 10 times normal. Dividing the meter reading by 10 results in an accurate current quantity.

FIG. 4-27

AMMETER CIRCUIT



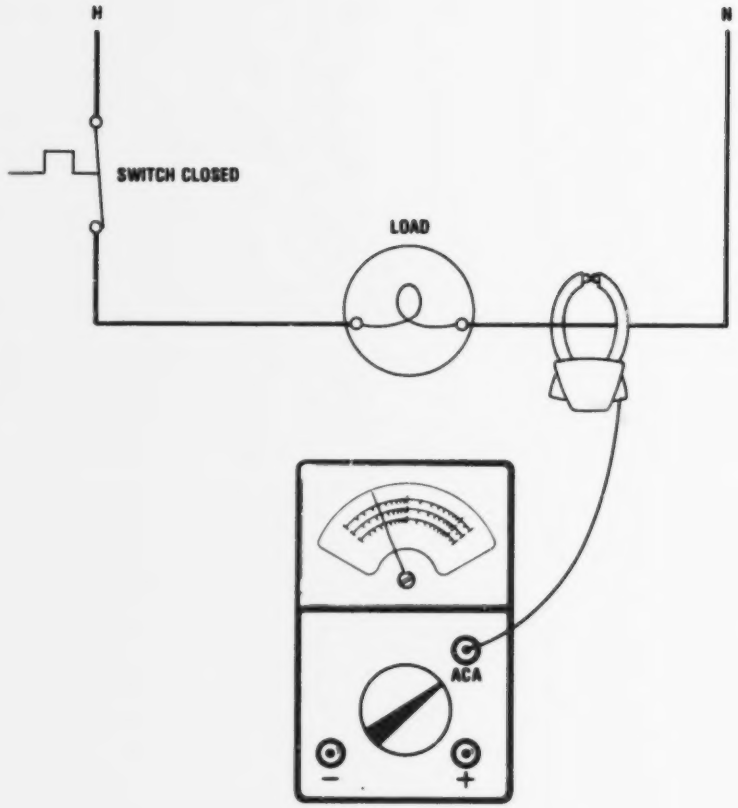
MEASURING CURRENT

Handling and Care of Instruments

Electrical measuring instruments are delicate tools. Because of this they should be handled with care and should be stored in a cool, dry place. Dropping an instrument may dislodge the movement coil from its mount. Always store instruments in a meter case when not in use. Always disconnect leads when not in use.

FIG. 4-28

CLAMP-ON AMMETER



Test Lights and Continuity Testers

Although volt meters and ohmmeters are quite necessary in verifying electrical values, test lights and continuity testers are also quite useful. Test lights are economical and simple to operate. They can be used to verify the presence or absence of voltage, whereas voltmeters are most valuable in measuring the exact value of applied voltage. Continuity testers are also economical test devices. They can verify that a circuit exists or if switch contacts are open or closed. An ohmmeter is most valuable in measuring the exact value of resistance and in determining continuity in very high resistance circuits.

BEST DOCUMENT AVAILABLE

Both meters and testers have their places in installing and/or troubleshooting appliance systems. If both test devices are available, the main criteria which determines which device should be used is; what is being measured (existence or value) and the familiarity of the operator with both test devices.

ELECTRICAL COMPONENT TESTING

Switches

The ohmmeter can be used to test switches, however, *no* voltage can be applied to it. A switch in a closed position will have little or no resistance. If the switch is open, it will have an infinite resistance. Thus, an ohmmeter can be used to check whether a switch is actually closed or open. In practice, the resistance of the switch need not be measured. The ohmmeter can simply be used to test for continuity across the switch. Again, it is important to always isolate the component (disconnect wiring, turnoff voltage supply) when using an ohmmeter. This procedure prevents the possibility of a false (feedback) reading.

The voltmeter can also be used to test a switch, particularly if it must be tested with the circuit energized. If the switch is closed, voltage shown across the terminal should be zero (electricity seeks the path of least resistance, through the switch). With the switch open, the voltage should be equal to the circuit voltage. Voltage drop across a closed switch may indicate corroded, dirty, or faulty contacts and/or terminals.

Resistive Loads

Resistive loads such as heater strips and ignition elements can be checked for continuity using an ohmmeter to detect damage or breaks. If the design resistance of the component is known, the reading can actually be measured and compared with the design-rated value.

Electromagnetic Loads

Electromagnetic loads can be tested for continuity and, generally speaking, should always form a continuous circuit. Many electromagnetic loads consist of numerous wire coils wrapped around an iron core. Shorting, due to the insulation breakdown between adjacent coils, can cause a malfunction. This condition might not be detected by a continuity test and therefore may require the use of an ohmmeter.

Motors

The only testing generally performed on the electric motors used in gas appliances is to determine if the electrical fault is in the motor or its control components. Supply voltage to the motor can be measured with a voltmeter. If supply voltage is correct and the motor does not operate properly, it should be removed from the appliance. If the motor is at fault, it is usually replaced or taken to a specialized motor rebuilding shop for more detailed trouble-shooting and repair.

Circuit Testing

The wide variety of electrical circuits used in gas appliances prohibits a detailed discussion of circuit testing. However, certain general techniques can be used in trouble-shooting electrical circuits. The techniques listed below should be considered as general guideline rather than a step-by-step process to be followed in solving a specific problem.

1. Symptom gathering.
2. Problem diagnosis.
3. Visual examination.
4. Testing.
5. Analysis of test results, and conclusions.
6. Repair and/or parts replacement.

In symptom gathering, the problem is defined in terms of the appliance failing to perform its design function. Obviously, the statement "it doesn't work" is insufficient information. A more specific description of symptoms is needed. This specific information may be obtained from the homeowner, but more likely the serviceman may have to examine and operate the appliance to observe them himself.

Having determined the problem's specific symptoms they must be diagnosed in terms of their cause. This diagnosis involves deciding which specific circuits and component may be involved, and mentally noting which components in that circuit or circuits should be checked for proper operation. A visual examination of these circuits and components may reveal an obvious reason for the problem, such as the appliance fuse being faulty.

Components and/or circuits are then tested. The results of these tests are analyzed and conclusions drawn. Based on these conclusions, components are either repaired or replaced and the appliance tested to ensure that the problem has been corrected.

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

SECTION 5
BASIC HEATING SYSTEM CONTROL COMPONENTS

PRINCIPLES OF CONTROLS

Gas heating appliances utilize heat energy produced by fuel gas combustion. Heating appliances are equipped with a wide variety of controls which regulate and control the flow of gas to the appliance burners, as well as operate auxiliary equipment. Modern heating appliances have manual and automatic controls which function by mechanical, electrical, or thermal means. The resulting control systems provide a high degree of reliability, efficiency, and safety.

Operating controls cause the appliance to perform its intended function. *Safety controls* prevent hazardous operation. Sometimes, one type of control performs both functions.

Gas is a safe and useful fuel, but without proper appliance operation, hazards are possible. *Safety controls* are therefore incorporated in gas appliances to override or act independently of operating controls to prevent hazardous conditions. These safety controls either shut down equipment or act to relieve excessive temperature or pressure when hazardous conditions are present.

Operating controls regulate appliance operation by controlling the flow of fuel (as by thermostats) and other mechanisms (such as fans). These operating controls may allow unattended (automatic) operation of appliances and can help the appliance or equipment to operate in a safe and more efficient manner. Safety and Operating control functions can be performed manually or automatically by mechanical, electrical, or thermal means.

Manual controls

The simplest controls are manually-operated mechanical devices such as manual gas valves. The supply valve on a small space heater is an example of this type of control. When operating the heater, the user judges the amount of heat required and, while watching the flame, adjusts or throttles it by operating the gas valve. Manual controls can also be electrical devices, such as a fan selector switch which controls a blower. Manual controls are usually simple components and may actually be part of more complex automatic controls.

Automatic controls

For example, almost all larger space heaters sold today are automatic, whereas 40 years ago manual operation was most common. In some appliances, manual control is impractical or even impossible due to safety, operating sequence, or accessibility of the appliance. Most often, automatic controls are used because they are far superior to manual controls in the efficient utilization of gas in the appliance. Thermostats are examples of automatic thermal controls which sense the temperature and automatically control the appliance to maintain a selected temperature. Some automatic controls are simple mechanical devices. Mechanical float valves, which control the addition of make-up water to a boiler, are an example of a simple mechanical automatic control.

BASIC ELEMENTS OF CONTROLS

Every control system includes three basic elements: the sensing device, the actuator and final control element.

The sensing element measures the operating condition. With manual control, the appliance user performs this function. With automatic control, a device in the thermostat senses the temperature and controls the appliance operation.

The actuator receives the signal from the sensing element and applies the force required to operate the final control element. In manual control of

space heating appliances, the user normally operates the gas valve by hand. Automatic control systems which use expanding fluid or metal, provide the force needed to operate a valve. In many control systems, the force is supplied by electricity, either at line voltage (120 volt or 240 volt) or at a reduced control voltage (24 volt or millivolt level). Whether manual or automatic, the actual control function is performed by the final control element.

MANUAL CONTROL COMPONENTS

Tapered Gas Valves

The most common type of manual gas valve consists of a tapered plug inside a body as shown in Figure 5-1. Both the plug and body have a porting through them. When the plug is turned so the ports line up, gas will flow through the valve. The porting may be closed by turning the plug a quarter turn. This action blocks the flow of gas. The plug is usually held snugly in the body by a tension spring. A lubricant is used between the metal surfaces of the plug and body to seal against leakage and to lubricate the metal surfaces.

Because of the tightly fitted surfaces, even light corrosion can cause the valve to stick. For this reason, tapered gas valves are generally constructed of bronze or brass to prevent corrosion.

FIG. 5-1

MANUAL GAS VALVE

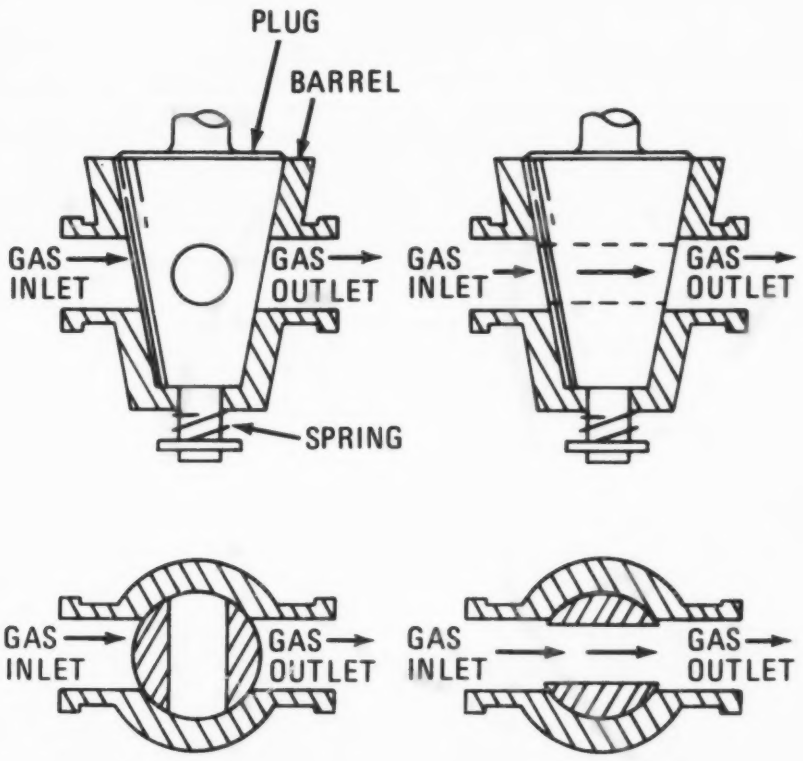
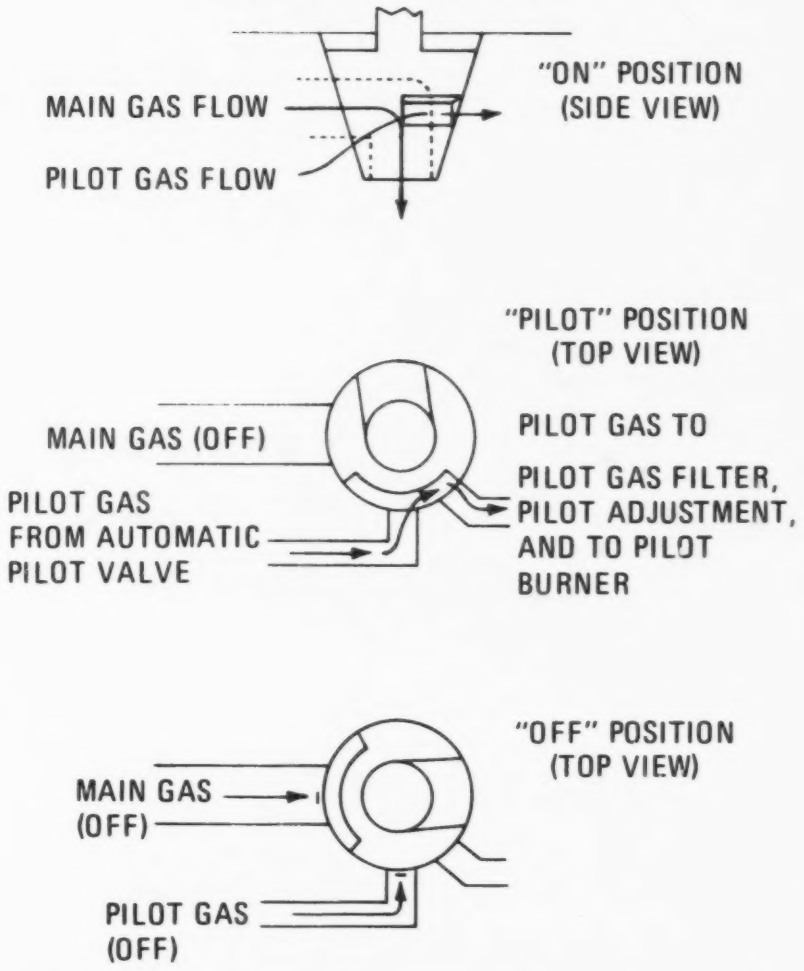


FIG. 5-2

MULTIPLE POSITION VALVES

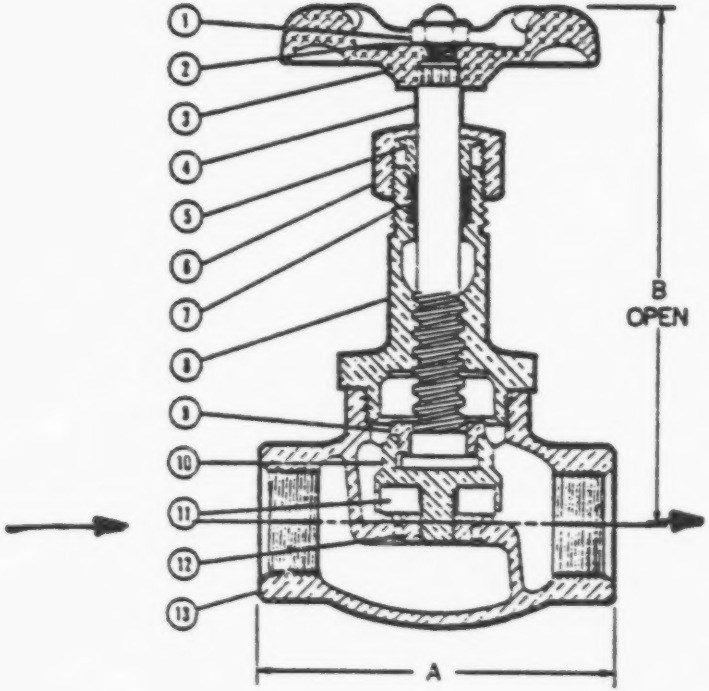

"ON" POSITION (SIDE VIEW)
MAIN GAS FLOW
PILOT GAS FLOW
"PILOT" POSITION (TOP VIEW)
MAIN GAS (OFF)
PILOT GAS TO
PILOT GAS FILTER, PILOT ADJUSTMENT, AND TO PILOT BURNER
PILOT GAS FROM AUTOMATIC PILOT VALVE
"OFF" POSITION (TOP VIEW)
MAIN GAS (OFF)
PILOT GAS (OFF)

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

FIG. 5-3A

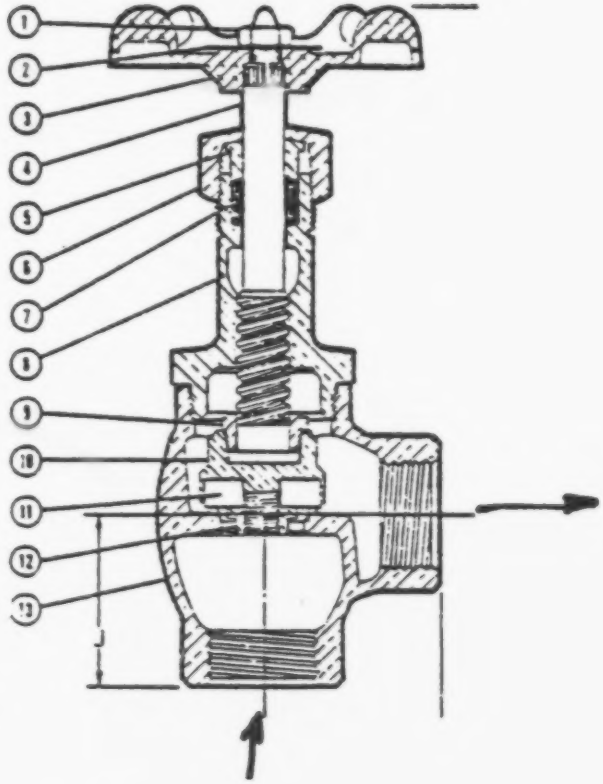
GLOBE VALVE



PART
1. Handwheel Nut
2. Identification Plate
3. Handwheel
4. Stem
5. Packing Gland
6. Packing Nut
7. Packing
8. Bonnet
9. Disc Holder Nut
*10. Disc Holder
11. Seat Disc
*12. Disc Nut
13. Body

FIG. 5-3B

ANGLE VALVE



Tapered gas valves are virtually maintenance free. If, under adverse conditions, the valve becomes stiff and difficult to turn, it can be disassembled, cleaned and lightly lubricated with suitable lubricant. Badly scored or leaking valves should be replaced.

The National Fuel Gas Code and most building codes require that a manual shutoff valve be placed in the gas supply line, no more than six feet upstream of the appliance controls. This valve is used to shut off the gas supply when servicing or replacing the appliance and in case of an emergency.

Multiple Position Valves

Multiple position valves have two or more portings through which gas may flow. When lighting the pilot burner, the valve is turned part way to a mechanical stop built into the valve body. In this position the valve allows gas to flow only to the pilot burner. Once the pilot is lighted, the valve is rotated to another position to allow gas to flow to both the pilot and the main burner. Figure 5-2 shows the various positions in which the valve can be set. Multiple position valves are frequently incorporated within automatic or combination valves used in many heating applications.

BEST DOCUMENT AVAILABLE

Globe and Angle Body Valves

Globe and angle body valves are used in water piping to allow installation and maintenance of an appliance without disturbing the water supply to other appliances. In hydronic systems, inline cutoffs allow maintenance to be performed on components without having to drain the entire system.

The globe valve body (See Figure 5-3a) is constructed with inlet and outlet chambers separated by a partition. The valve port is formed in this partition with a circular round seat. Angle valve bodies (See Figure 5-3b) are similarly constructed except that the inlet and outlet are at right angles to each other. In the open position, the valve disc is in the full up position. As the threaded valve stem is rotated, the disc moves down toward the valve seat. In the closed position, the disc is held against the valve seat, providing a tight seal. Globe valves are often fitted with a replaceable disc. Typically, globe and angle valves are installed with the inlet of the valve positioned so that water must flow against the open disc rather than on top of the open disc.

Needle Valves (manual)

Needle valves are used if flow regulation, as well as cut-off, is required. A needle valve is similar to a small globe valve except that a conical-shaped disc extension is added. As the valve is closed, the extended needle begins to restrict flow through the valve port long before the disc reaches the cutoff position. Further rotation of the valve stem causes further restriction of flow until it stops. This gradual restriction of flow provides accurate control when flow rate adjustment is required, for example, as an adjustment for pilot burners.

Electrical Switches

Manually operated switches can be used to control various components of heating appliances including valves, fans, pumps, and other equipment. Electric power must be available, but the application may call for remote manual operation. The remote operation can add convenience and simplicity to the control system.

AUTOMATIC CONTROL COMPONENTS

As previously stated, many automatic control components use heat sensitive devices to detect changes in temperature. Typically, bimetals and diastats are used as the sensing element. In addition, other automatic control components use sensing elements which detect the flow of a gas or a liquid. Still other automatic control components use sensing elements which detect the level of a liquid.

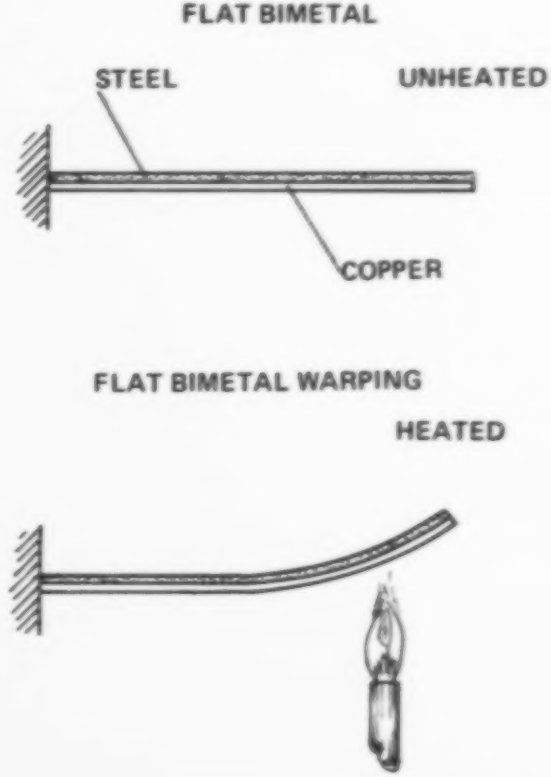
Bimetals

A bimetal is a heat sensitive device made from two dissimilar metals bonded together. Since the two metals have different physical characteristics, when heated one will expand at a faster rate than the other. The connecting bond prevents any movement between the two metals so both metals bend or warp.

Bimetals are used in heat sensitive switches, control devices, and protective devices. In wall thermostats, for example, bimetals are used to sense room temperature and actuate other control components.

Bimetals are manufactured in a variety of shapes and sizes to suit the different temperature ranges and applications. Figure 5-4 shows a flat bimetal in both heated and unheated conditions. This type of bimetal is frequently used in fan and limit switches.

FIG. 5-4



BEST DOCUMENT AVAILABLE

FIG. 5-5

DISC BIMETAL

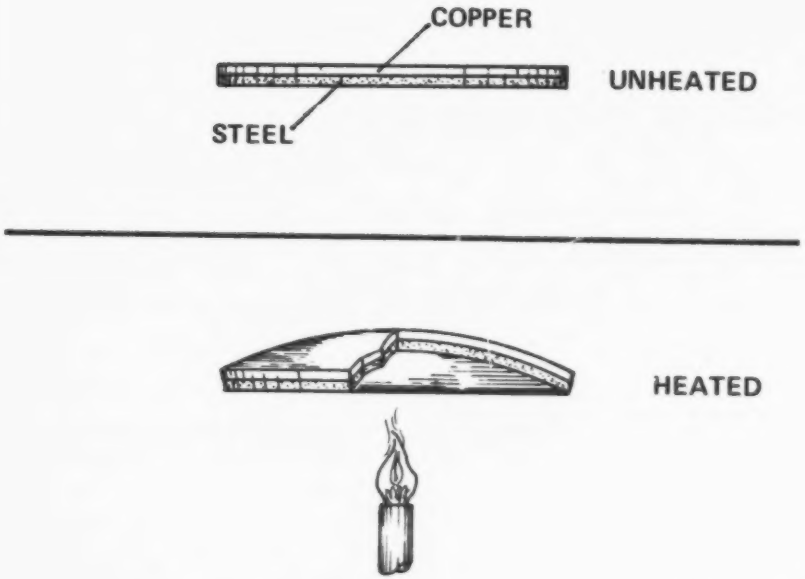


Figure 5-5 shows a disc bimetal which snaps up and down, making or breaking an electrical contact. Disc bimetals are also frequently used in fan and limit switches.

A horseshoe or "U" type bimetal is shown in Figure 5-6. Its prongs warp toward or away from each other, making or breaking an electrical contact. This type bimetal may be found in wall thermostats and some types of pilot safety systems and thermal vent dampers.

Figure 5-7 shows a helix bimetal which is usually fastened at one end and rotates clockwise or counterclockwise when heated or cooled. Usually the other end is attached to a shaft and cam mechanism. As the helix bimetal rotates, the cams activate switches. This type bimetal is commonly found on modern fan/limit combination switches, some types of thermal vent dampers and thermometers.

FIG. 5-6

HORSESHOE-SHAPED BIMETAL

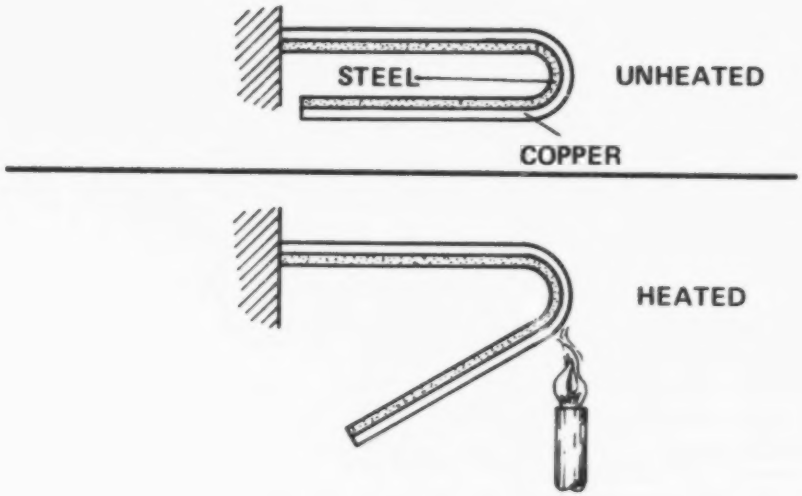


Figure 5-8 shows a coiled watch spring bimetal. When heated or cooled, this bimetal turns clockwise or counterclockwise, making or breaking an electrical contact. This type bimetal is commonly found in thermometers, wall thermostats and some types of thermal vent dampers.

Though there are several different types of bimetals, they all function in the same basic manner. For this reason, failures are relatively the same with all types. The most common causes of failure are:

(a) The bimetal becomes permanently warped. This can occur when the bimetal is overheated or develops *metal fatigue* or weakens due to age.

(b) The bimetal cracks or breaks. This occurs due to metal fatigue or physical abuse.

Bimetal control devices are normally replaced rather than serviced. In some applications the bimetal may be *calibrated* (readjusted) to function satisfactorily.

Diastats

The diastat is a simple temperature sensing device containing a liquid or gas which expands when heated. This expansion increases the pressure within the assembly. The increase in pressure is used to activate a valve or electrical contact.

BEST DOCUMENT AVAILABLE

FIG. 5-7

HELIX BIMETAL

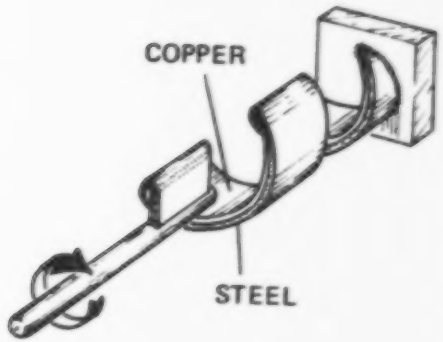


FIG. 5-8

WATCHSPRING-SHAPED BIMETAL

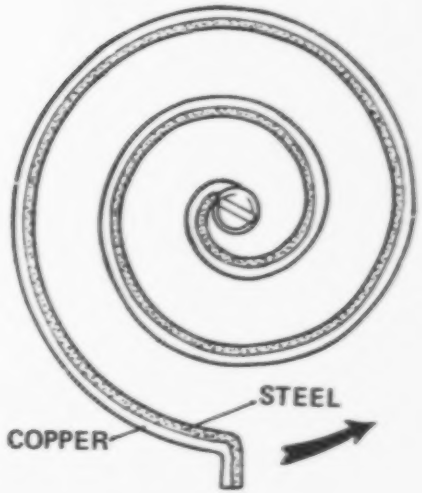


FIG. 5-9

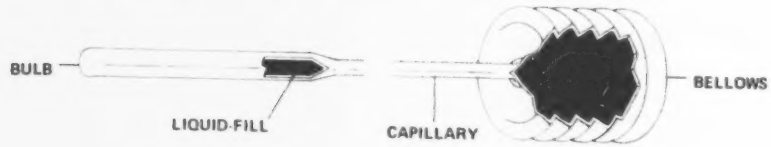
OIL-POWERED DIASTAT WITH DIAPHRAGM

FIG. 5-10

MERCURY-POWERED DIASTAT

FIG. 5-11

OIL-POWERED DIASTAT WITH BELLOWS



Generally, all diastats consist of four component parts (See Figure 5-9). The first part is the *liquid-fill* or fluid. Oil-based fluids and mercury are the most commonly used. The second part is the bulb, which serves as a reservoir for the fluid. Third, there is a capillary or hollow connecting tube. Fourth, there is an expandable metal diaphragm or series of diaphragms called a bellows.

The diastat in Figure 5-9 contains all four components and is commonly found in hydraulic temperature-sensing thermostat and aquastat controls. The diastat in Figure 5-10 does not utilize a bulb. In this case, the capillary serves as a fluid reservoir as well as connecting tube. The diastat in Figure 5-11 utilizes all four basic components and incorporates an expandable bellows.

BEST DOCUMENT AVAILABLE

Oil powered diastats are similar in construction to the units shown in Figure 5-9 and 5-11, with variations in bulb size and capillary length. A precise amount of oil-based fluid is sealed within the assembly. Most oil-powered diastats are constructed of copper, but in applications with extremely high temperatures, steel diastats are often used. Oil powered diastats are commonly used on controls which maintain relatively accurate temperatures.

A common mercury-powered diastat is shown in Figure 5-10. Mercury-powered diastats are very similar to oil-powered diastats, differing primarily in the fluid used and ruggedness of construction. Mercury-powered diastats are usually constructed of heavier materials in order to withstand the high vapor pressures created when mercury is heated. Mercury diastats normally utilize a diaphragm assembly rather than a bellows and are commonly incorporated in controls used as safety devices.

Since most mercury diastats are used in safety devices, the heavy construction is essential. The pilot flame is normally in direct contact with the diastat so the liquid-fill must be a stable and rugged material. Mercury fulfills this requirement, providing reliability and longer service life.

Oil powered diastats are subject to the following operating problems:

1. Excessive heat due to control malfunction may cause the diastat to rupture. Any loss of fluid from the sealed diastat assembly will cause erratic operation of the particular controlling device.
2. A kink or sharp bend in the hollow capillary may cause erratic operation of the particular controlling device.

Oil-powered diastat assemblies are not usually available for replacement. Therefore, if the diastat fails for any of the reasons mentioned, the entire controlling device must be replaced.

Mercury-powered diastats are subject to the following operating problems:

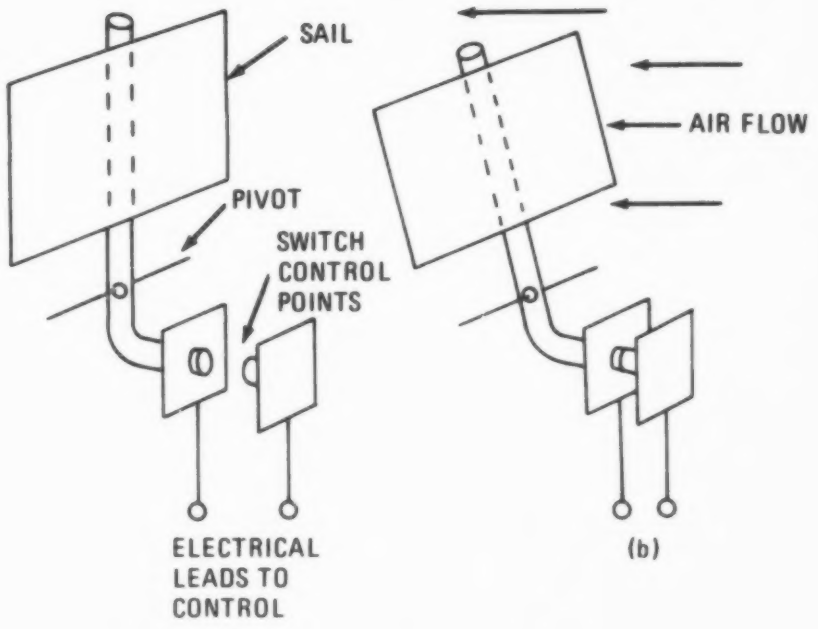
1. If the pilot flame which heats the diastat is adjusted too high, the vaporizing mercury can generate excessively high pressures which may rupture or permanently expand either the diastat tip or the diaphragm walls. Also, if the pilot flame heats the diastat to a cherry red color, it will shorten the life of the mercury diastat. Proper adjustment of the pilot flame should heat the tip of the diastat to a dull red color.
2. A kink or sharp bend in the hollow capillary may cause erratic operation of the control device. Replacement mercury-powered diastat assemblies are usually available if the diastat fails.

Sail Components

Sails are simple devices designed to sense the flow of fluid or air. A typical sail consists of a light metal or plastic plate mounted on a pivot. Movement of the sail plate is transmitted by a simple linkage to an electrical switch or other device to be actuated. A typical sail switch is shown in Figure 5-12.

FIG. 5-12

SAIL SWITCH



In the appliance, sails are installed so the flow of fluid or air to be sensed will strike the sail plate. With no flow, the sail is held in position by either a light spring or gravity. When the flow begins, it strikes the sail, causing it to tip and close, or open the switch contact points.

Float Components

Floats are bouyant devices used to sense liquid level. The bouyant float is connected by mechanical linkage to a control device. The float and linkage are typically constructed of corrosion-resistant materials. Frequently, the linkage extends through the wall of the appliance so the control device is isolated from the liquid. Floats are often used to mechanically activate valves. They can also be arranged to actuate an electrical switch which controls an electrically-operated control device located elsewhere.

BEST DOCUMENT AVAILABLE

In Figure 5-13a, the float is lifted by the liquid in the vessel. As the float reaches a set level, the valve to the liquid source is closed. The valve disc is closed by suitable linkage connected to the float. If the liquid level drops in the vessel, as in Figure 5-13b, the float drops with the liquid level, opening the supply valve. Liquid then flows into the vessel until the liquid again reaches its original level, as in Figure 5-13a. At this position the float causes the valve to close, stopping the flow of liquid into the vessel.

BUOYANT FLOAT CONTROL

FIG. 5-13A

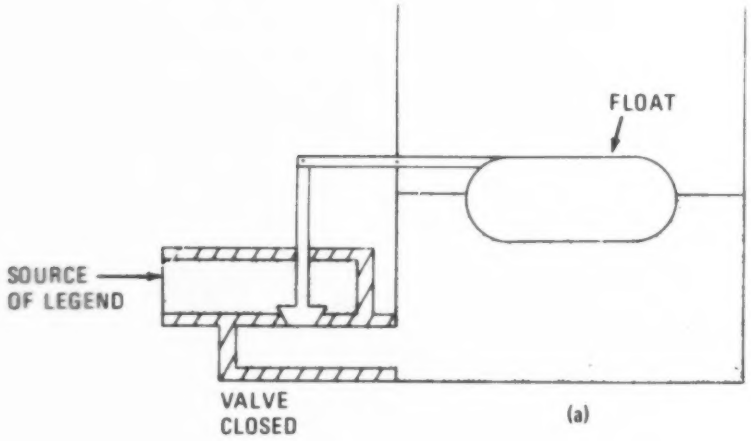
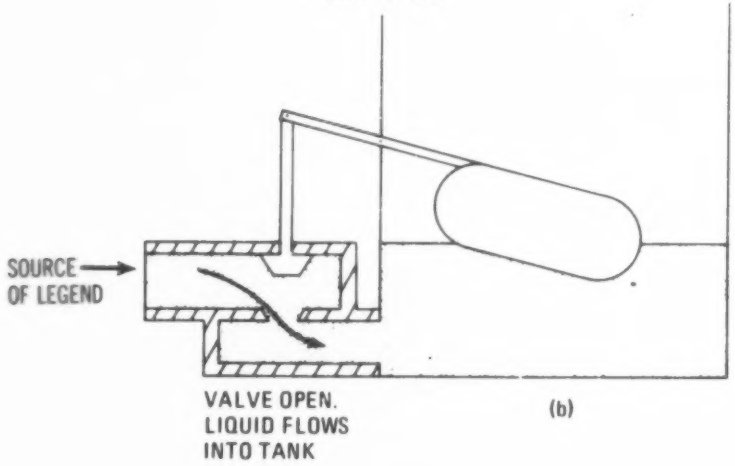


FIG. 5-13B



A similar arrangement can also be used to open or close an electrical switch, rather than a valve. This switch, in turn, may be used to open or close an electrically operated valve. An additional function of the control may be to shut off the gas supply to an appliance (such as a boiler) when the liquid level drops to a given value (low water cutoff).

Electrical Contact-Type Liquid Level Sensors

Electrical contact-type liquid level sensors take advantage of the electrical conductivity of some liquids to sense the liquid level in an appliance. Two *low-voltage* probes are immersed in the liquid (See Figure 5-14a) and the electrical circuit is complete. If the liquid level in the vessel drops so that the upper probe is out of the liquid (See Figure 5-14b), the electrical circuit is broken, thereby activating or deactivating the liquid control. Of course, wiring of the two probes must be electrically insulated from the appliance and the liquid.

Contact-type liquid level devices are subject to malfunctions resulting from corrosion of the contacts and the buildup of scale on the conducting surfaces. Good system and maintenance design can minimize this problem, but if it does occur, cleaning or replacing of the contacts will generally correct the problem.

TYPICAL APPLIANCE AUTOMATIC CONTROLS COMPONENTS

Thermostats and Temperature Limit Controls

Thermostats and limit controls are automatic temperature-sensing devices which control the appliance operating and safety functions.

In warm air heating systems, room thermostats maintain the desired temperature of the dwelling by controlling the appliance burners. Fan controls operate the circulating fan to distribute the heat produced.

Hydronic systems are typically controlled by room thermostats which control the flow of heated fluid to radiators in the dwelling. Depending on the design of the system, the thermostat may control a circulating pump, valves placed in the system to control the flow of heated fluid or the main burner gas valve. In other types of boilers, an aquastat controls the burners so water temperature is maintained within the desired operating range.

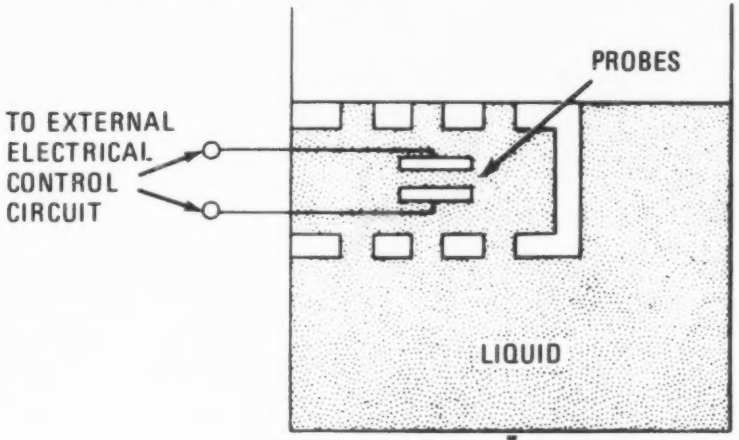
In all cases, limit controls sense over-heating conditions and shut off gas supply to the appliance before a hazardous situation or damage results.

Limit controls are available in a variety of sizes and shapes. Some controls use a bimetal disc which opens and closes an electrical switch. Other types may use a bimetal element formed in the shape of a helix. This type turns a shaft and cam as the helix bimetal is heated or cooled. This action opens or

BEST DOCUMENT AVAILABLE

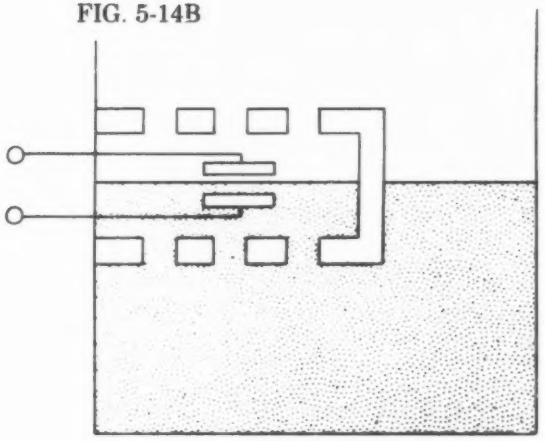
FIG. 5-14A

ELECTRICAL CONTACT-TYPE LIQUID LEVEL SENSOR



(a) CIRCUIT "CLOSED"

FIG. 5-14B



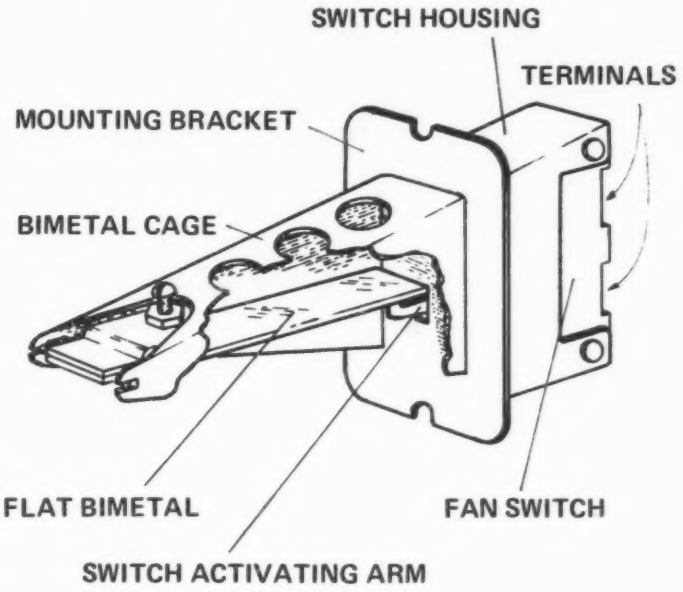
(b) CIRCUIT "OPEN"

closes an electrical switch. Still another type uses a straight bimetal strip. Several types of bimetal controls are shown in Figure 5-15, 5-16, and 5-17.

A variety of bimetal operated limit controls are manufactured to meet the requirements of various applications. Some are adjustable; others are nonadjustable. Some provide normally open electrical contacts, most however are normally closed. They may be designed to operate at both line voltage (120 volts) and at reduced voltage levels (24 volts or millivolts).

FIG. 5-15

FLAT BIMETAL FAN CONTROL



Bimetals are widely used in thermostats because of their ability to sense small thermal changes and produce a physical movement. This movement is then typically used to actuate an electrical switch. Bimetal operated controls vary in complexity from simple nonadjustable limit switches to complex room thermostats incorporating time clocks, fan and cooling selector switches, and other auxiliary controls.

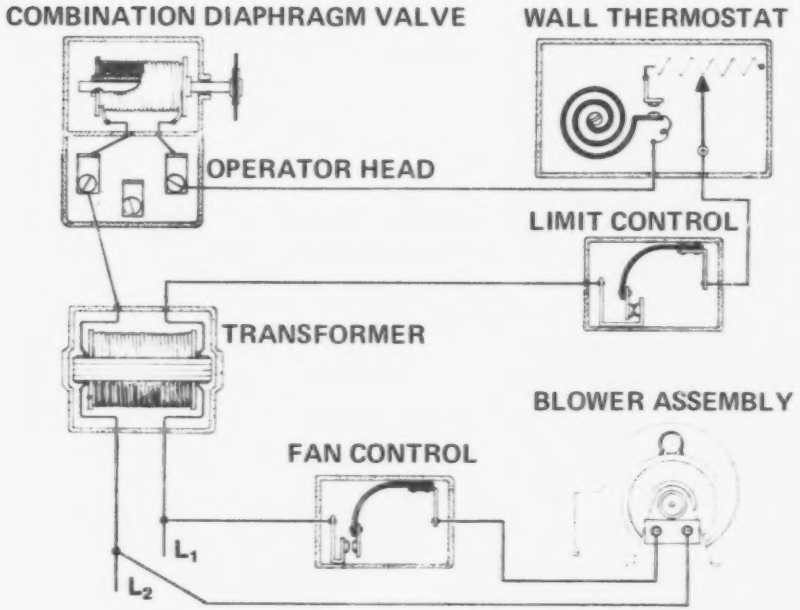
Bimetal room thermostats commonly used with heating appliances include a bimetal heat sensing device which opens and closes an electrical switch. This switch controls the appliance operation and therefore maintains the desired temperature in the dwelling. A typical room thermostat utilizing a straight bimetal is shown in Figure 5-18.

To change the thermostat setting, a cam and temperature setting indicator are provided. As the indicator is rotated from one position to another, the cam rotates, changing the position of the spring-loaded lever and bimetal. If a higher room temperature is desired, the lever and cam force the bimetal toward the stationary contact. Therefore, the room temperature must increase for the bimetal to automatically move away from the

BEST DOCUMENT AVAILABLE

FIG. 5-16

BASIC 24 VAC SYSTEM SCHEMATIC



stationary contact. If a lower room temperature is desired, the indicator is rotated and the lever and cam apply less force on the bimetal. Therefore, the room temperature must decrease in order for the bimetal to automatically move toward the stationary contact.

Room thermostats also utilize bimetal coils as shown in Figure 5-19. In this arrangement, a mercury-type switch is fastened to a coiled bimetal. When the bimetal coil is heated by the surrounding room air to the temperature set on the thermostat (See Figure 5-19a), the mercury switch is tilted so the mercury runs to the end of the tube away from the switch electrodes. This action breaks the circuit. As the room cools the bimetal coil opens (Figure 5-19b), tilting the mercury switch so that the mercury flows to the other end of the tube. With both electrodes immersed in the mercury, the switch is closed and turns on the heating appliance.

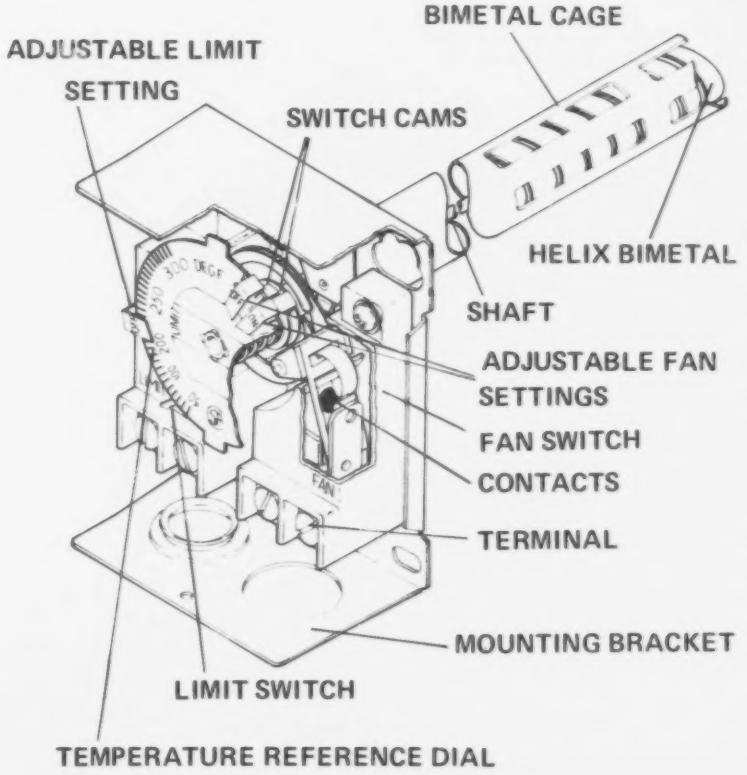
Room thermostats may operate at line voltage, low voltage, or millivolt levels. Most residential thermostats operate at low voltage, 24 volts AC. The chief advantage to this type of thermostat circuit is that low voltage wiring is safer and easier to install than 120 VAC wiring. In addition, less arcing takes place at the thermostat contacts. Finally, low voltage thermostats can be designed for more accurate temperature control. This is primarily due to the less sensitive, heavy construction of 120 VAC thermostats.

Hydraulic-Type Controls

Hydraulic thermostats, aquastats, low limit and high limit controls utilize diastats to perform a variety of safety and operating functions. These devices are widely used in boilers to shut off the gas flow to the burners if the maximum allowable temperature is exceeded. They are also used as operating controls, cycling burners on and off to maintain the water temperature within normal operating limits. A typical diastat-operated aquastat control is shown in Figure 5-20.

FIG. 5-17

HELIX BIMETAL COMBINATION LIMIT AND FAN CONTROL



BEST DOCUMENT AVAILABLE

FIG. 5-18

BIMETAL SENSOR ROOM THERMOSTAT

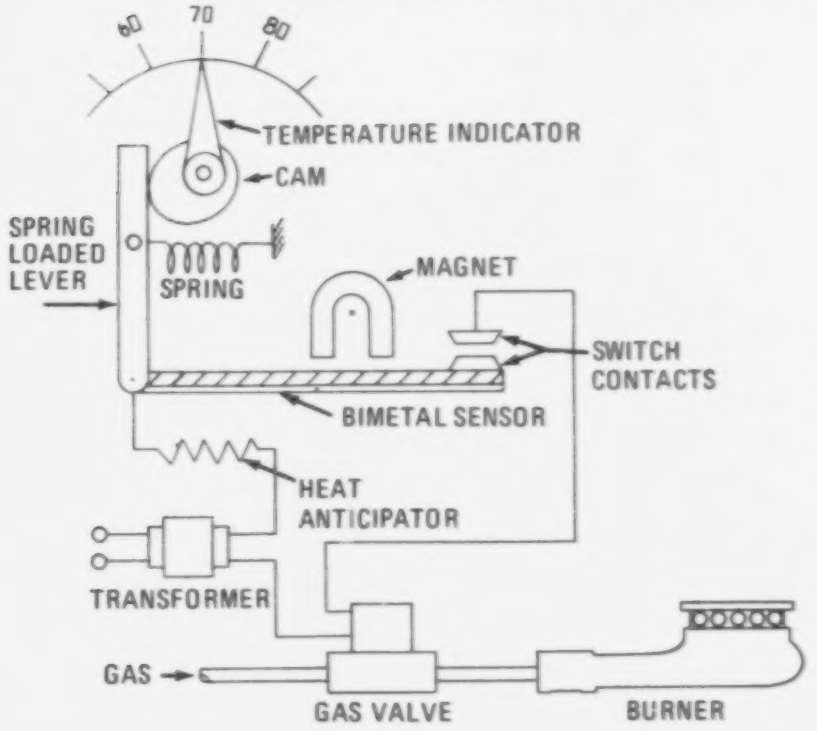
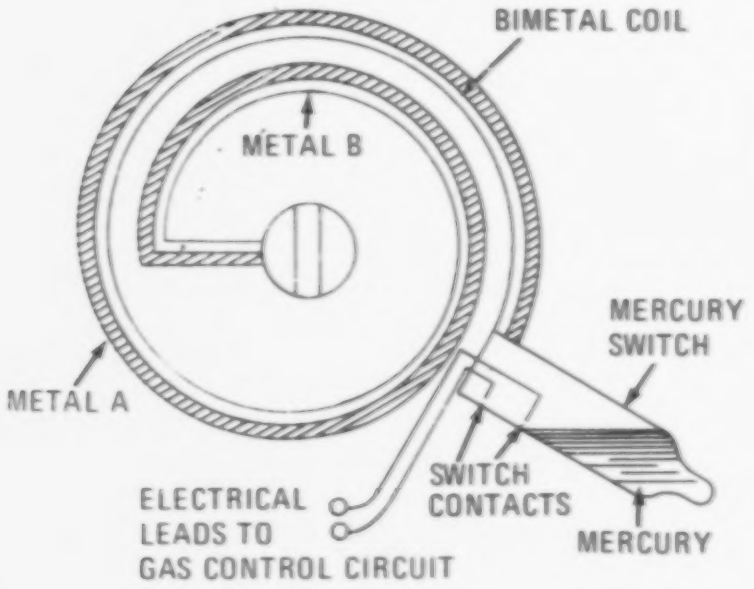


FIG. 5-19A

BIMETAL COIL ROOM THERMOSTAT



(a) SWITCH OPEN. GAS VALVE CLOSED

Normally, the diastat bulb is immersed in the boiler water, generally by inserting it through a special fitting in the boiler wall. The limit control or aquastat contacts may be wired to control an electrically operated gas valve, circulating pump, or other device. Contacts generally allow for adjustment of the control to suit a particular operating requirement. A single control may be equipped with several sets of contacts to perform multiple functions (i.e., high and low limit, circulating pump, etc.).

PILOT SAFETY SYSTEMS

All gas appliances require some means of igniting gas at the burner. Most heating appliances are equipped with automatic pilots. These devices perform two basic functions: they automatically light the gas at the main burners and shut off the gas supply to the main burners if the pilot flame is extinguished.

A pilot safety system normally consists of a pilot burner and an electromagnetic safety shutoff valve or electrical switch. This safety device includes a thermocouple or thermopile which either actuates a gas shutoff valve electromagnetically or operates a switch in the gas valve circuit.

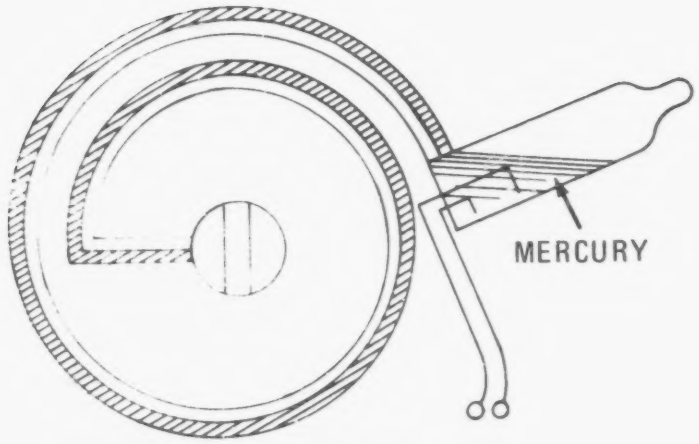
Some pilot systems use bimetal sensors or diastats to open or close an electrical switch. In turn, this switch acts to control flow of current to an automatic control valve which electrically "proves" the existence of a pilot.

Thermoelectric valves, on the other hand, use the current generated by thermocouples heated by the pilot flame to hold a safety valve open. Thermopile-type automatic pilots generate sufficient current to power both the safety and main gas valve.

The independent safety valve is a globe pattern design and normally made of aluminum or brass. Connections are provided in the valve body for gas inlet, gas outlet, and in most cases, a separate pilot gas supply. A thermocouple or thermopile is installed with the hot junction exposed to

BEST DOCUMENT AVAILABLE

FIG. 5-19B



(b) SWITCH CLOSED. GAS VALVE OPEN.

the pilot flame and the leads connected to the valve. An electromagnetic power unit (solenoid) is built into the valve and connected to the thermocouple lead. The power unit is arranged so that when activated by the thermocouple, it will hold the main shutoff disc and valve open.

A typical thermoelectric valve is shown in Figure 5-21. In order to light the pilot burner, the reset button must be pushed down to manually open the pilot valve. With the reset button depressed, gas cannot flow to the main burner. After the pilot flame is ignited, the reset button must be held down for 30 to 60 seconds until the pilot flame heats the thermocouple. Once hot, the thermocouple will develop enough electrical current to power the electromagnet and holds the main shutoff disc and valve open. With the reset button released and the multi-position valve rotated, gas is available to flow to the main burner. If the pilot flame is extinguished, the thermocouple cools and stops producing the electrical current which holds the valve open. Gas flow to the pilot burner and main burner is shut off depending on many factors, usually within one minute.

Automatic pilot safety valves are subject to a variety of malfunctions. Symptoms of common malfunctions with causes and corrective actions are given below:

Symptoms	Causes	Corrective Actions
1. Gas odor around valve.	1. Leaking seals in valve body.	1. Dismantle valve, replace seals.
	1. Main shutoff disc not properly seated.	1. Clean valve, replace springs or replace valve as required.
	1. Thermocouple damaged.	1. Check thermocouple lead connections. Check location of hot junction in pilot flame. Check output with millivoltmeter. Replace as required.
2. Gas odor around main burner.	2. Electromagnetic power unit inoperative.	2. Replace power unit.
3. Pilot burner lights on manual reset but will not stay on.	3. Pilot clogged with lint.	3. Clean lint from air port or burner.

AUTOMATIC GAS VALVES

Solenoid-Operated Valves

Solenoid-operated gas valves are utilized when electrical control of gas flow to the main burners is required. A typical application would be to control main burner gas flow in response to a thermostat or aquastat. In this case, automatic safety pilot functions are provided in a separate device.

The solenoid-operated gas valve (See Figure 5-22A) is normally a globe pattern aluminum valve with the valve stem extended and connected to a plunger. The plunger fits into a guide tube which maintains the position of the valve stem and disc and provides a seal between the valve's gas and electrical portions. An electrical coil surrounds the guide tube.

When electrical power is applied to the solenoid, such as by a thermostat or aquastat, the solenoid coil is energized. Its magnetic force attracts and lifts the iron plunger, as in Figure 5-22B, compressing the spring and lifting the valve disc off the valve seat. The passageway through the valve is thus opened, and gas flows through the valve. When electrical power to the solenoid is cut off, the magnetic field collapses and the weight of the plunger and valve disc, aided by the spring, closes the valve. In older

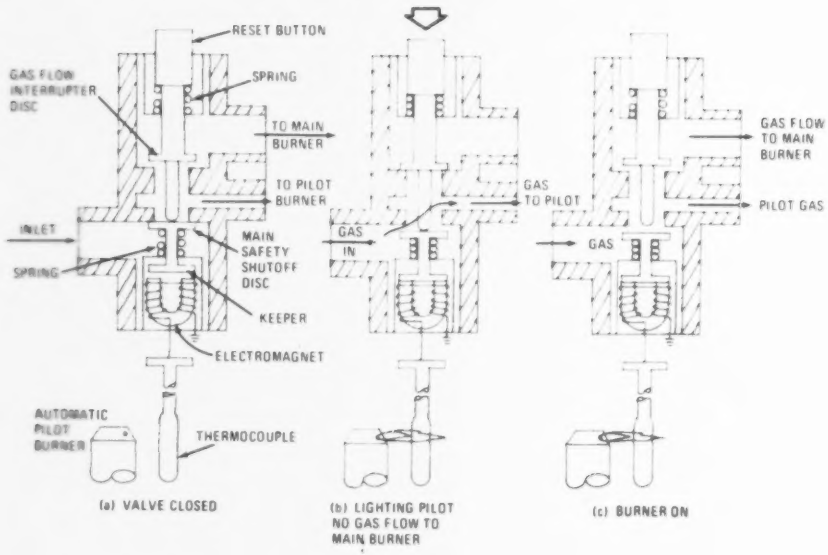
BEST DOCUMENT AVAILABLE

FIG. 5-20

AQUASTAT (DIASTAT OPERATED)

FIG. 5-21

THERMOELECTRIC VALVE



solenoids this action is quite rapid and usually creates a clacking noise. Newer solenoids have a hydraulic (oil) bath to dampen the motion of the moving parts, reducing operating noise.

Solenoid valves are used in many types of applications. Most heating appliance solenoid valves require either external 24 volt or 120 volt AC. It is important to note that many solenoid-operated valves also use a *Manual Operator* or manual operating device. This device is used during an electrical failure so that the valve and/or appliance burners can be operated manually. When improperly used or when improperly installed, valves which use manual operators can be dangerous; in that during a power failure heat distribution devices are inoperative (i.e., blower motor, circulator motor, etc.).

Typical solenoid valve malfunctions are either physical or electrical. Physical problems such as valve leakage, corrosion, and foreign particle interference with valve operation are common to all globe-type valves.

FIG. 5-22A

SOLENOID-OPERATED GAS VALVE

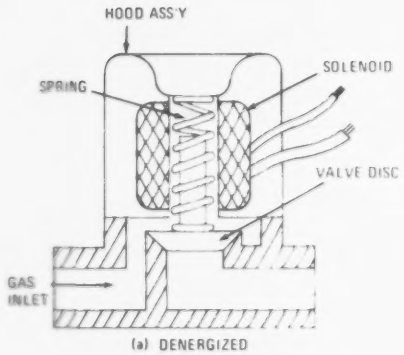
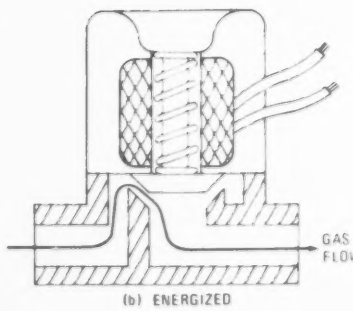


FIG. 5-22B

SOLENOID-OPERATED DIAPHRAGM VALVE



BEST DOCUMENT AVAILABLE

Electrical problems are generally either a shorted coil or an open coil. If the coil is open, a voltage check across the terminals should show full operating voltage and a continuity check should show an infinite resistance. The valve will not open.

If the coil is shorted, it or other components such as the transformer may overheat or burn out. In the case of electrical malfunctions, the coil and/or the entire valve should be replaced.

Modulating Gas Valves

Modulating gas valves are main gas valves which vary gas flow; as well as providing "full flow" and "no flow" control. The modulating feature can be incorporated into most types of gas valves. however, their use is restricted to limited space heating applications.

For example, when a control device (Thermostat or Aquastat) cycles "on" the gas valve of a hot water boiler, the gas valve allows full flow to the main burners. On some boilers, as the temperature of the water increases, the gas flow is *throttled* to a *minimum flame* rather than cycling completely off. The minimum flame helps to maintain a more constant water temperature without full gas flow. As additional heat is required, the modulating valve opens and increases the gas flow.

If the water temperature exceeds a pre-set value, the modulating valve cycles completely off.

FIG. 5-23

REMOTE BLEED — MECHANICAL DIAPHRAGM VALVE

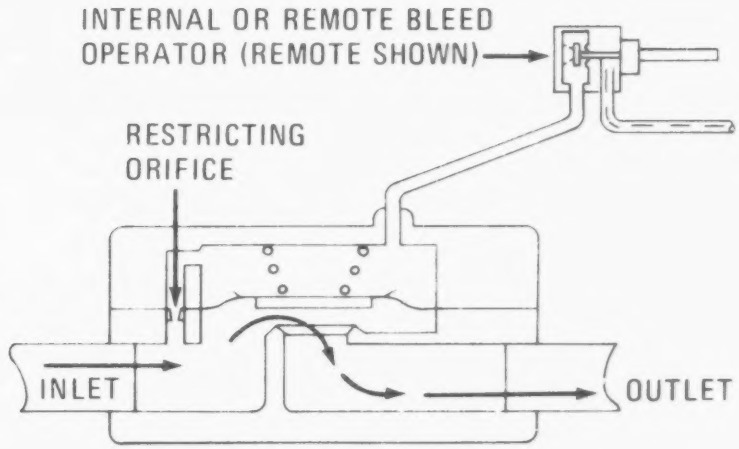
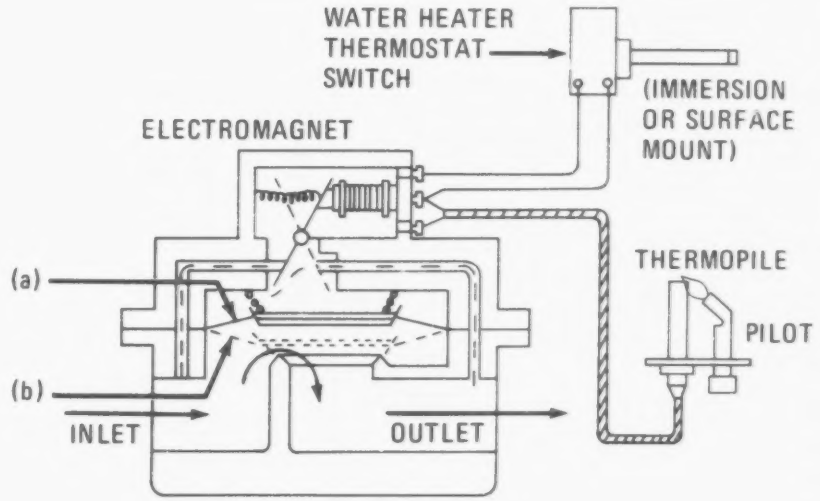


FIG. 5-24

INTERNAL BLEED — ELECTRICAL DIAPHRAGM VALVE



Combination Diaphragm Valves

Combination diaphragm valves utilize a small valve to control the flow of *bleed gas*. This bleed gas acts against the diaphragm to open and close the valve. Combination diaphragm valves can be used in many applications and with different activating mediums (electric, hydraulic, pneumatic). A typical diaphragm valve is shown in Figure 5-23.

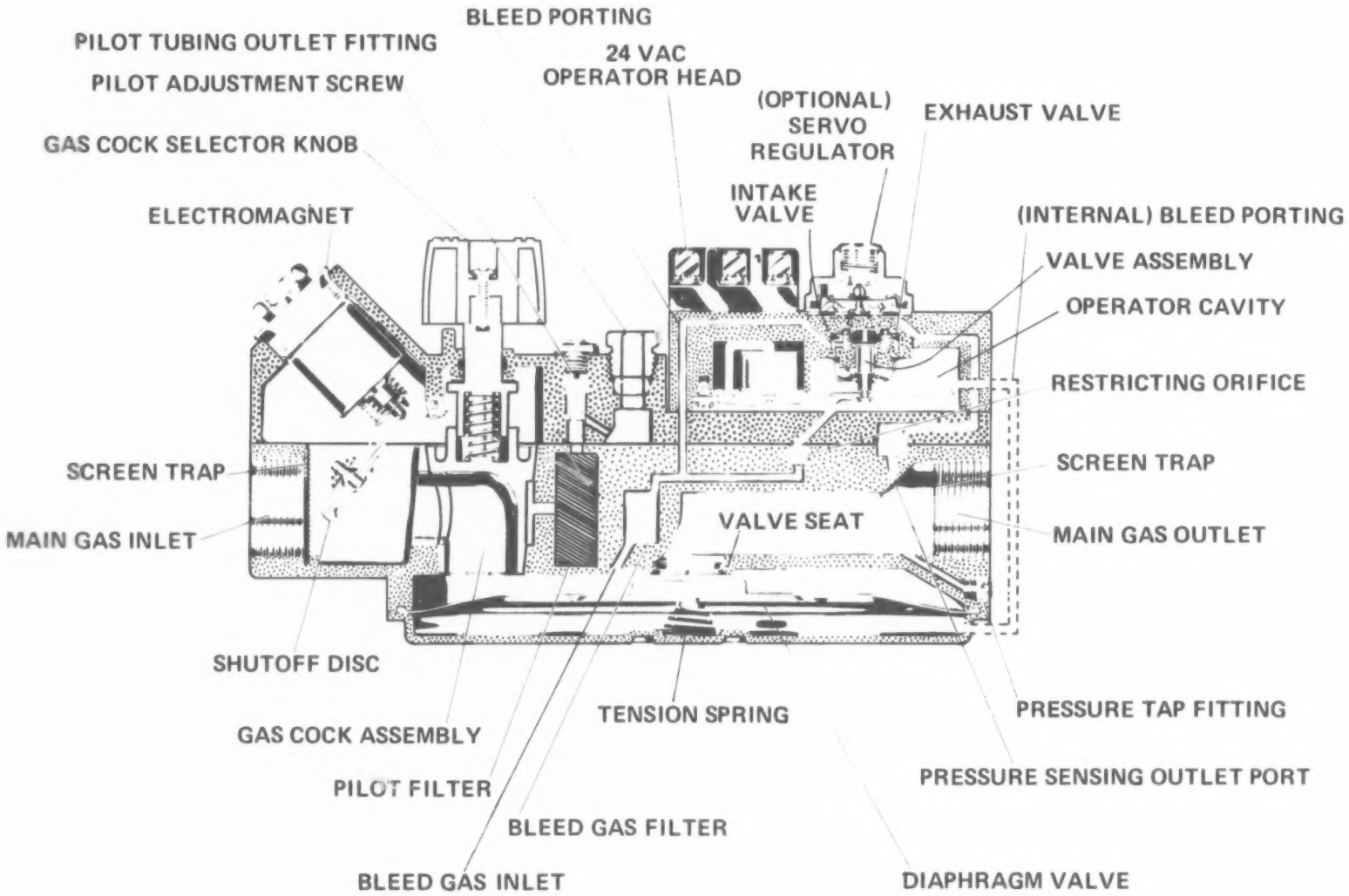
Diaphragm valves use a circular chamber divided into an upper and lower housing by a partition. The partition contains a valve port while the diaphragm contains a valve seat. The upper chamber is further divided by a spring-loaded flexible diaphragm. Shut off is accomplished by bleed gas pressure in conjunction with the pressure exerted by the spring above the diaphragm. This action forces the diaphragm down and onto the valve seat.

Bleed gas enters from the inlet side of the valve to the chamber above the diaphragm. The chamber remains pressurized (valve closed) until an electrical, hydraulic, or pneumatic operator valve opens. As the operator valve opens, bleed gas is allowed to escape from the upper chamber and out of the valve. This depressurization allows the diaphragm valve to open and

BEST DOCUMENT AVAILABLE

FIG. 5-25

COMBINATION DIAPHRAGM VALVE



BEST DOCUMENT AVAILABLE

gas to flow to the main burner. The operator valve is normally controlled by a thermostat (electrical), diastat (hydraulic), or mechanical valve (pneumatic).

Figure 5-24 illustrates a more recent electrical, internal bleed-type diaphragm valve. The valve is shown in both the open (a) and closed (b-dotted) position. The valve shown in the illustration is of the electrical type. A thermopile provides the operating voltage for the system and the thermostat or aquastat controls the electrical signal to the diaphragm valve operator.

In this case, the electrical operator opens and closes a bleed gas inlet and outlet porting. As in the previous example, the diaphragm valve is in the open position. The electromagnet in the operator has a lever-type valve assembly attached which closes the bleed gas inlet and opens the bleed gas outlet. When this occurs, the valve is said to be depressurized of bleed gas, and the diaphragm valve opens.

When the temperature setting of the aquastat is satisfied, the contacts open and break the circuit to the operator. Because of the return spring attached to the inlet and outlet valve, the inlet valve opens and the outlet valve closes (see b position, Figure 5-24). This action simply allows bleed gas to re-enter the area above the diaphragm and pressurize the chamber. As a result, both the bleed gas pressure and spring tension apply a downward force on the diaphragm which closes the diaphragm valve. When the contacts of the aquastat close, the cycle is repeated.

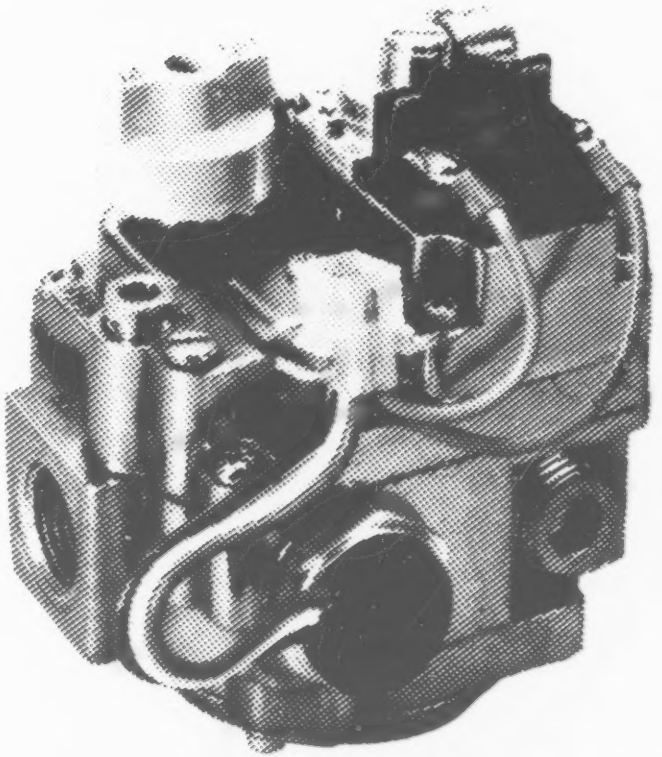
Basically the only differences between the valves shown in Figure 5-23 and 5-24 are: an electrical *vs.* a mechanical operator and external *vs.* internal bleed gas outlet. The internal bleed porting is preferred because it eliminates the frequency of malfunction. For example, the bleed gas in Figure 5-23 is purged from the valve and simply burns away at the pilot flame. If the tubing outlet becomes obstructed, the diaphragm valve will not open.

Modern Combination Diaphragm Valves

Modern combination diaphragm valves incorporate several different control functions into one control body. A typical control of this type will include a multiple-position manual valve, pilot safety shutoff assembly, and a solenoid-operated diaphragm valve. Some controls may, in addition, include a pressure regulator or other auxiliary control. A typical modern combination diaphragm valve is shown in Figure 5-25.

The multiple-position manual valve is included to provide safe lighting of the appliance pilot. The valve typically has three positions—OFF, PILOT and ON. The "OFF" position positively blocks gas flow to both pilot burner and main burner. The "PILOT" position permits gas flow to the pilot and the "ON" position makes gas available to the main burner. The multiple-position valve permits safe ignition of the appliance pilot and prevents main burner operation until the pilot lighting sequence is completed.

FIG. 5-26 REDUNDANT GAS VALVE



The pilot safety shutoff included in combination controls is similar in design and operation to the pilot system discussed earlier. The arrangement of the valve may be physically different, however, the basic components and concept are the same.

The combination diaphragm valve supplies gas to the main burner. The operating signal is supplied by controls outside the combination diaphragm valve, such as a remote wall thermostat, hydraulic diastat, etc. Valve construction and operation is similar to the independent solenoid-operated diaphragm valve discussed earlier.

With the addition of a gas pressure regulator, the combination diaphragm valve becomes a complete and self-contained control capable of performing all gas flow control functions of many heating appliances.

BEST DOCUMENT AVAILABLE

Most combination control valves have modular design so components can be replaced or added, as needed to meet the requirements of a particular appliance. This design allows economical replacement of individual componenets without replacing the entire control.

Redundant Gas Valves

In certain conditions, space heating appliances which use vent dampers and/or intermittent ignition devices must also use *redundant gas valves*. Redundant gas valves use two valves to control the flow of gas to the main burner (See Figure 5-26). They are used because, under certain conditions, there is a remote possibility that trash, in the gas supply, could prevent a single valve from fully closing. Two valves, serving the same function, almost completely eliminate this possibility.

Redundant gas valves are similar in design to combination diaphragm valves except for the additional main gas valve. Installations where redundant gas valves are required, usually involve the replacement of the existing gas valve. However, the installation of an additional gas valve (similar to the original) meets the requirements for a redundant gas valve.

BEST DOCUMENT AVAILABLE

SECTION 6

GAS SPACE HEATING SYSTEMS

GAS SPACE HEATING SYSTEMS

This section presents the common variations of gas space heating systems, their operation and malfunctions. Although the systems vary in structure and operation, all indirectly transfer heat, created by fuel gas combustion, to a desired area within a structure or space. The heat transfer medium may be either air or heated water.

FORCED AIR HEATING SYSTEMS

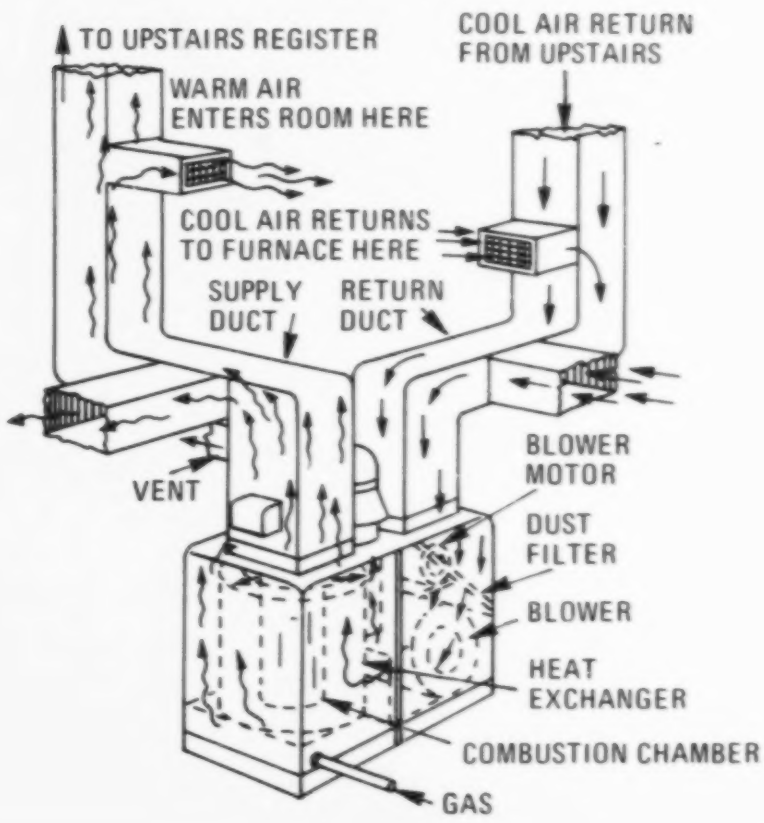
Furnaces which directly heat and circulate air throughout the dwelling are very popular. In this type of system, heat generated by fuel combustion within the furnace is transferred to air which, in turn, is distributed throughout the building. The heated or conditioned air is distributed from the furnace through ducts in the building structure. Products of combustion are isolated from the conditioned air and are exhausted to the outdoors through a venting system.

Older, warm air furnaces and even some currently being built rely totally on the natural tendency of warm air to rise to circulate the heated air throughout the dwelling. These furnaces, known as gravity furnaces, must be located below the dwelling in a basement or crawlspace. Many of them do not use ducts to distribute the conditioned air. When ducts are used, they must be rather large to minimize resistance to the slight air flow. In addition, the conditioned air is not filtered in these systems.

In most modern warm air furnaces, air is circulated by a fan or blower. These forced air furnaces may be installed almost anywhere, including basements, attics, utility rooms, and outdoors. Heated or conditioned air is evenly distributed and air is filtered as it enters the furnace. Properly sized modern forced air furnaces can be fitted with auxiliary equipment such as humidifiers, electronic air cleaners, and sometimes air conditioning, with little or no system modifications. A typical forced warm air system is shown in Figure 6-1.

FIG. 6-1

FORCED WARM AIR SYSTEM



BEST DOCUMENT AVAILABLE

Forced Air Furnace Basic Structure and Operation

Several different styles of forced air furnaces are manufactured for different applications. These styles basically include the up-flow, down-flow, and horizontal flow systems.

Up-Flow Furnaces

In the up-flow furnace, the fan is located at the bottom of the furnace cabinet (see Figure 6-2). Air is drawn through a filter, passes through a fan or fan blower, moves upward across the heat exchanger, and is discharged into a network of warm air supply ducts at the top of the furnace.

FIG. 6-2
UPFLOW

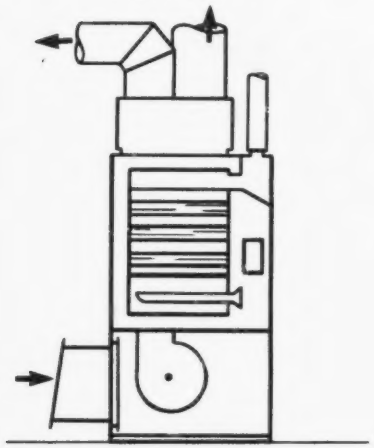


FIG. 6-3
DOWNFLOW

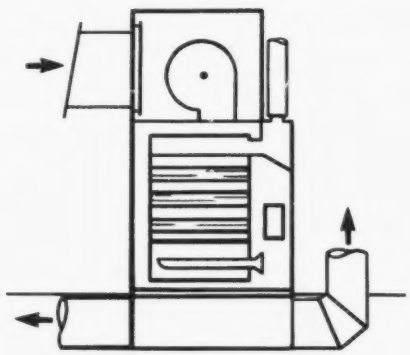
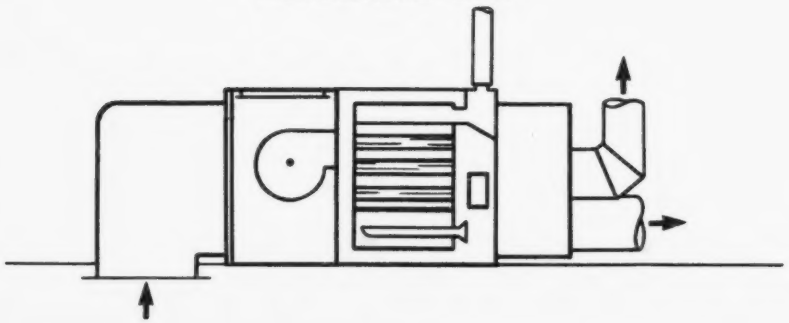


FIG. 6-4
HORIZONTAL FLOW



When the thermostat calls for heat, the main gas valve opens, allowing gas to flow to the main burner. The constant pilot or other ignition device ignites the main burner flame. Hot combustion gases rise through the heat exchanger creating a draft which draws air into the combustion chamber to support the combustion of the fuel gas.

As detailed in Section 3, as the combustion gases exit the flue passage of the heat exchanger, they enter the draft diverter or draft hood. Dilution air is drawn from the appliance space and into the diverter where it combines with combustion gases. The diluted gases then enter the venting system and exit into the atmosphere.

Heat created by combustion is transferred to the inner surface of the metal heat exchanger. When the temperature on the outside surface of the heat exchanger reaches a predetermined temperature, a fan control automatically activates the fan motor. Air is drawn into the fan or blower and is forced over the outer walls of the heat exchanger. The air picks up heat as it travels across the exchanger and is then forced into a series of ducts. The conditioned air is then routed into the various rooms or zones of the building.

If sufficient heat energy is not removed from the heat exchanger, the exchanger will overheat. This is frequently caused by a dirty filter or faulty fan motor. Because this condition could result in damage to the furnace and/or building, a limit control is installed near the heat exchangers. If the overheating occurs, the contacts of the limit control open and the gas supply to the main burners is extinguished.

Many systems return cooler air from the various rooms back to the furnace blower. Other systems draw return air from outside the building. At the blower, the air is filtered, distributed through the furnace, and routed back into the supply ducts. Some forced air systems do not use return air ducts; instead, they draw air directly into the furnace return opening. This can be hazardous and has been prohibited by most national and local codes. Such systems can circulate combustion products in the house.

When the temperature of the building rises to the selected setting, the thermostat contacts automatically open. This action closes the main gas valve which extinguishes the main burners. The fan continues to operate until the heat exchanger cools to a predetermined temperature. When this occurs, the fan control contacts open and the fan stops.

It should be noted that, under certain conditions, during the "off" cycle conventional space heating appliance systems waste useful heat. For example, if the appliance is located in a conditioned air space or space which is not open to the outdoors, heated air is drawn out of space due to the temperature difference between it and the outside air. In addition, at the end of the "on" cycle, potentially useful *residual heat* rises from the appliance heat exchangers, enters the vent and exits into the atmosphere.

BEST DOCUMENT AVAILABLE

Down-Flow Furnaces

In a down-flow furnace, the fan is located above the heat exchanger (see Figure 6-3). Air enters through a filter at the top of the furnace and moves downward through the fan compartment and across the heat exchanger. Warm air is discharged into distribution ducts at the bottom of the furnace. Down-flow furnaces are often called counterflow or reverse flow furnaces because distribution air moves downward across the heat exchanger. This style furnace is generally installed in buildings without basements.

Although the flow of conditioned air through a down-flow furnace is opposite from that of an up-flow furnace, its operation is quite similar. Because conditioned air is distributed from the bottom of a down-flow furnace, a special base may be required. In addition, a secondary limit control is usually located near the fan in the top of the furnace. The additional limit interrupts burner operation in the event the fan malfunctions.

Horizontal-Flow Furnaces

In horizontal-flow furnaces, the fan is located at one end of the heat exchanger (see Figure 6-4). Air enters through the filter and is drawn into the fan or blower. The air is then forced across the heat exchanger in a horizontal direction. Once across the exchanger, the conditioned air is distributed into the supply ducts on the opposite end of the furnace.

Because of their short vertical dimension, horizontal furnaces are generally installed in locations with limited headroom, such as attics, crawlspaces, below floors, and in some cases, suspended below ceilings. Horizontal furnaces operate in much the same manner as up-flow and down-flow furnaces. However, as with down-flow systems, a secondary limit control is usually located near the fan or blower. This protects against overheating caused by reverse flow before the fan is energized.

Operating Components

Gas forced air heating furnaces use several sub-components and controls to achieve efficient combustion and control of the fuel gas.

Warm air furnaces are equipped with a gas manifold which connects the gas supply piping, incorporates all gas controls, and distributes the gas directly to the main burners. As you know, National Fuel Gas Code requires that a manual shutoff valve be installed upstream of the furnace and within 6 feet of the gas supply to the furnace. This allows shutoff of the gas supply in the event of an emergency or when the appliance is serviced.

The gas manifold is often equipped with an independent pressure regulator, automatic safety valve and main gas valve. However, most later furnaces use a combination valve where all three valve functions are incorporated into one device.

The main burner controls the mixing of air and gas for combustion and determines the size, shape, and nature of the flame. The main burner is located at the bottom of the furnace heat exchanger so that rising hot combustion gases will evenly heat the exchanger's inner surfaces. Figure 6-5 shows a typical arrangement of main burners and heat exchangers in a warm air furnace.

Automatic safety pilot systems serve two functions in warm air furnaces: they ignite gas at the main burner and prevent a flow of gas to the main burner if the constant pilot flame is extinguished.

The pilot burner and thermocouple, or other sensing device, are generally located in the main combustion chamber adjacent to one or two main burners. Where several main burners must be ignited, a carryover or runner is commonly installed to provide ignition at all burners. The automatic pilot safety valve (or combination valve, if used) is located on the main gas supply manifold.

The automatic safety pilot system operates almost identical to the typical system described in Section 5. The pilot flame heats the thermocouple, producing an electrical voltage which energizes the electromagnetic power unit on the pilot safety valve (or combination valve). If the pilot flame is extinguished, the thermocouple cools, decreasing the electrical voltage, de-energizing the electromagnetic power unit, shutting off the gas flow. A schematic diagram of the automatic safety pilot system is shown in Figure 6-6.

Although the thermocouple and power unit is perhaps the most common safety system, other safety systems exist on earlier furnaces. A bimetallic strip and micro-switch (warp switch) are used as a safety control on some systems. Hydraulic diastat-operated safety controls are also used. These systems usually open an electrical switch in the valve circuit if the pilot is extinguished.

Fan Control System

The furnace fan or blower and associated components control circulation of heated air within the dwelling.

The fan or blower and motor are located in the furnace cabinet, on the return air side of the heat exchanger. Modern warm air furnaces use centrifugal, squirrel-cage-type blowers that are either connected directly to the motor, or to shafts or belts driven by the motor. The bimetal-type fan control is the most common type; however, diastat operated controls are also used. Both adjustable and non-adjustable controls are in use. In addition to thermal-type fan controls, solid state time delay relays may also be used to control the fan's operation.

BEST DOCUMENT AVAILABLE

FIG. 6-5

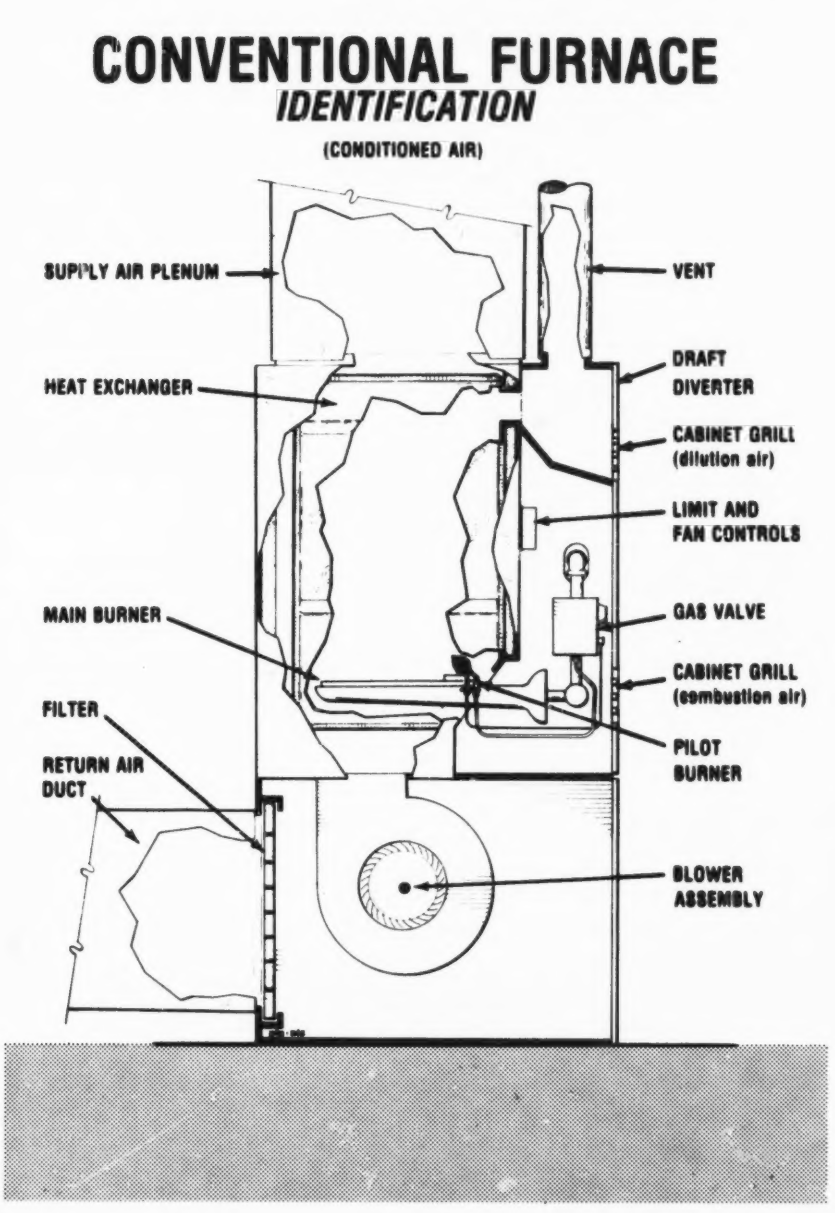
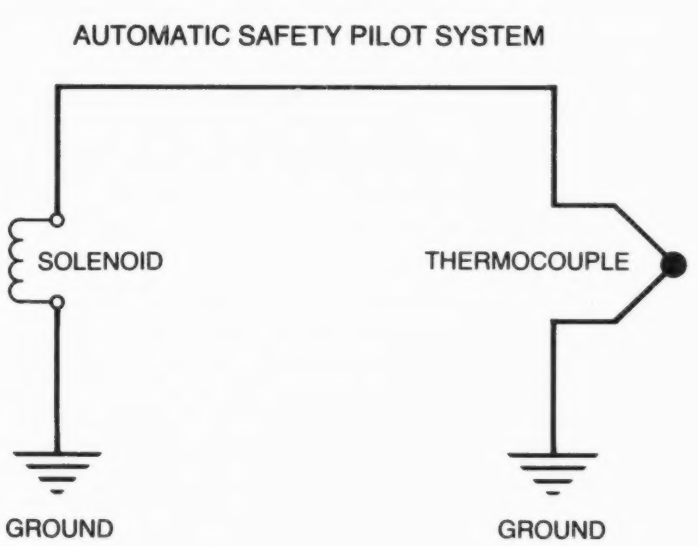


FIG. 6-6



Some room thermostats are equipped with a manual switch which can operate the furnace fan independently. In the normal heating cycle, however, the fan is automatically controlled by the fan control. Fan controls generally have normally-open contacts and are arranged in the control circuit to start the fan when the contacts close. The control may operate at line voltage to energize the motor directly, or it may operate at low voltage and energize the motor through a relay or contactor.

Most thermal fan controls are positioned so that their sensing elements are located near the heat exchanger. When the heat exchanger reaches a predetermined temperature, the fan switch contacts close, energizing the fan motor. This temperature is referred to as the "on" setting. This enables the furnace to reach operating temperature before air is circulated throughout the building. After sufficient heated air has been distributed into the building, the room thermostat acts to shut off gas flow to the furnace burners. The fan continues to operate until the fan control sensor cools to the "off" setting. At this point, the fan switch contacts open, turning off the fan. This arrangement permits *most* of the heat from the heat exchanger to be circulated into the building. The contacts of a typical thermal fan control are set to close around (fan on) 135 degrees F. and open around (fan off) 100 degrees F; or a 35° degree operating differential. These settings are adjustable on many types of fan controls.

BEST DOCUMENT AVAILABLE

The thermal fan control simply provides a delay. It delays the "on" action of the fan until the heat exchanger is hot enough to provide a useful heat transfer medium. In addition, it delays the "off" action of the fan until most of the useful heat has been transferred away from the heat exchanger.

A time delay relay provides the same function. Various delay times are available depending on the manufacturer's furnace. For example, a 120 second (2 minute) relay delays the on cycle of the fan 2 minutes after the main burners ignite, and the off settings, 2 minutes after the main burners are extinguished.

Since fan controls are exposed to temperature fluctuations and relatively high temperatures near the heat exchanger, corrosion and damage can occur and interfere with normal operation. Resistance across the switch can be measured in both the open and closed positions. If contact points are corroded or pitted, contact resistance will be high when in the closed position. If the fan control is defective, it should be replaced. Symptoms of common fan control malfunctions with causes and corrective actions are detailed in Figure 6-7.

FIG. 6-7

FAN AND LIMIT CONTROL MALFUNCTIONS

Symptom	Cause	Corrective Action
1. No main burner	1. Limit control failure	1. Replace limit control
	2. Manual reset required	2. Investigate cause of over-temperature, reset and observe operation carefully
2. Main burner comes on and "short cycles"	1. Fan Control failure	1. Check fan control for activition at specified temperature. Adjust or replace if necessary.
	2. Heat anticipator set incorrectly	2. Adjust anticipator
	3. Limit control "off" setting too low.	3. Adjust or replace as required.
3. Continuous Fan Operation	1. Fan control contacts stuck	1. Peplace fan control
	2. Fan "on" setting too low	2. Adjust fan control or replace as required.
4. Intermittent Fan Operation during continuous main burner operation	1. Fan control "on" and "off" setting too close (differential too short)	1. Adjust fan control where possible or replace as required.
5. Cool air from register at startup	1. Fan control "on" setting too low	1. Adjust or replace as required.
6. Cool air from register at shutdown	1. Fan control "off" setting too low	1. Adjust or replace as required

Temperature Limit Controls

Temperature limit controls are safety controls which shutoff the flow of gas to the main burner when the furnace exceeds its maximum operating temperature. In warm air furnaces, limit controls protect against hazards resulting from failure of the fan to operate properly, as well as other malfunctions which result in high temperature (obstructed filter, etc.).

The exact location of the limit control varies with the style and manufacturers of furnaces. Basically, all styles of furnaces utilize at least one limit control, located near the upper third of the heat exchangers. As previously mentioned, down-flow and horizontal furnaces usually have an additional limit control (secondary limit control) located near the blower.

Limit controls are very similar in design and construction to thermal fan controls. In fact, forced air furnaces often utilize a combination control which includes both a fan and a limit control. The major difference between fan and limit controls is that fan controls are normally-open, while limit controls are normally-closed switches.

The control system schematic in Figure 6-8 shows the limit in a typical circuit arrangement. When the temperature setting of the limit is exceeded, the control contacts open. This interrupts the circuit to the gas valve and/or power source causing the gas supply to be shut-off. Most limit controls are set to open the contacts at about 200°F.

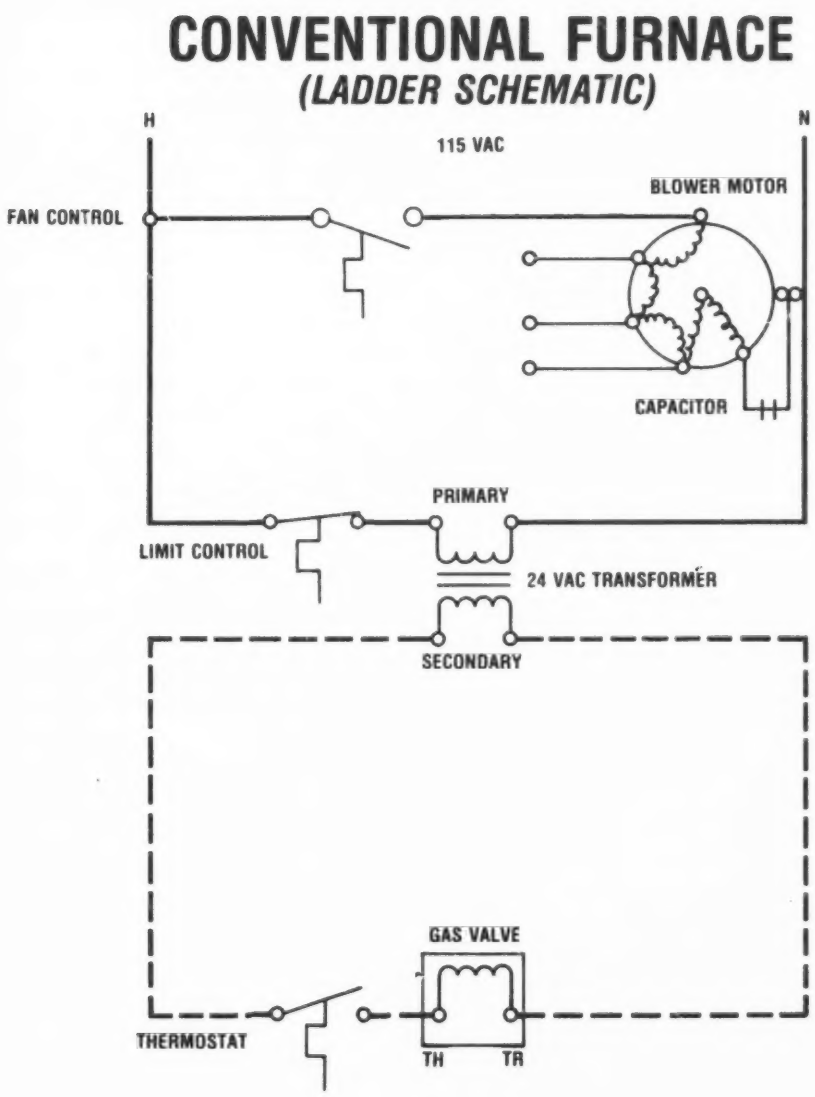
Some limit controls, especially secondary limit controls, must be manually reset if they activate. A manually resetable limit is used so the cause of overheating will be investigated before the furnace is placed back in operation.

Over long periods of time, temperature fluctuation can result in limit failure. Since the limit control contacts are normally closed, a continuity check across the terminals will indicate a failure of the contacts to conduct properly. If failure to open or premature opening of the contacts is suspected, the control should be removed from the appliance and monitored with an ohmmeter while heating the sensing element. Although it is difficult to measure the temperature at which the contacts open, an obvious malfunction in opening is usually easy to detect.

If circuit troubleshooting indicates a faulty limit control, it should immediately be replaced. Never allow the appliance to operate unattended without a limit control. Symptoms of common limit control malfunctions with causes and corrective actions are detailed in Figure 6-7.

BEST DOCUMENT AVAILABLE

FIG. 6-8



Thermostat Control Systems

Most warm air furnaces are operated automatically by room thermostats. The thermostat maintains the dwelling at or near the selected temperature. The thermostat controls the main gas valve, or other primary control; opening the valve when the dwelling temperature drops, and closing the valve when the temperature again reaches the selected setpoint.

Proper thermostat location is essential to satisfactory heating conditions. The thermostat must *not* be located near a window where the sun's rays can strike it and interfere with its operation. It should *not* be located on an outside wall where the temperature in winter is cooler. Also, it should not be located near supply air registers, lamps, television sets, or other heat sources. It should be located in an area of average air circulation within the living space of the building. Normal elevation of the thermostat is about 4 to 5 feet above the floor.

Most modern thermostats include a thermometer and, in some cases, a fan "on-auto" selector switch. The "on" position of the selector allows constant fan operation while the "auto" position allows fan operation only as required for heat distribution. Many thermostats also include a "heating-off-cooling" selector switch. This selector will only be used when air-conditioning has been added to the system.

Figure 6-8 shows a low voltage thermostat in a typical control system schematic. The system shown includes a transformer to provide 24 volt AC operating current. In this example, all controls with the exception of the fan circuit, operate at 24 volts.

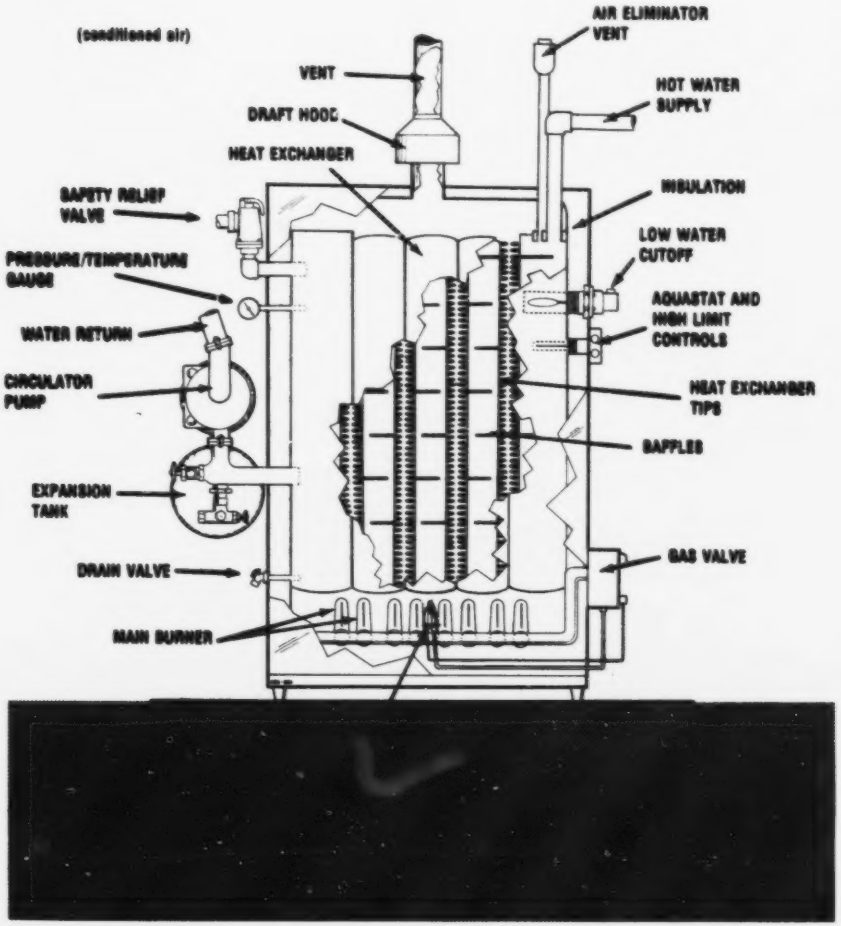
The majority of modern wall thermostats use a heat anticipator. The heat anticipator is a small variable resistor which is wired in series with the thermostat circuit. As the wall thermostat contacts close, the heat anticipator generates a small amount of heat within the thermostat cover and in the area of the bimetal. Because of this additional heat, the thermostat contacts open a few degrees prematurely. This is because the fan continues to operate after the thermostat contacts open. If a heat anticipator is not used, the room temperature would overshoot the set-point of the thermostat. The heat anticipator therefore makes it possible to maintain accurate temperature control. In most cases, the heat anticipator should be matched to the current draw of the thermostat circuit.

Modern thermostats are reliable devices and many complaints about their operation result from improper location, being out of level, or malfunction of related controls. Before extensive testing of the thermostat is begun, check for proper location, drafts, heat sources, etc. If these checks show no problems, check for proper operating voltage, heat anticipator setting, gas valve operation, relay operation, and wire and terminal condition. Gas valve and relay operation can often be checked by bypassing the low

BEST DOCUMENT AVAILABLE

FIG. 6-9

CONVENTIONAL HOT WATER BOILER
IDENTIFICATION



voltage thermostat with a "jumper" and temporarily observing the operation of the device. In addition, the hole in the wall from which the wiring exits should be as small as possible. Large wiring holes create drafts and alter the thermostats room temperature sensing capabilities. Malfunctions in the selector switches of the thermostat should be checked by referring to the thermostat subbase schematic and performing continuity checks on all switch positions.

HOT WATER BOILERS

Hot water boilers used as central heating appliances heat water which in turn is circulated through piping to radiators or coils. Heat released by the radiators or coils warms the dwelling. Products of combustion are confined to the boiler combustion chamber and flue passages and are vented outdoors through a venting system.

Hydronic hot water heating systems provide many advantages for central heating. These systems provide quiet, uniform heat. Room heat exchangers operate at relatively low temperatures, making them safe to touch. Although hot water does not store as much heat as steam, the excellent heat transfer characteristics of the water-backed heat exchanger make the overall system very effective.

Two kinds of hot water heating systems are in use. Early installations were gravity systems which relied on the density difference between cool and hot water to circulate the water. These systems have no pump and require large piping, large radiators or coils, and a large quantity of water. Because of the great mass which must be heated, these systems are slow to respond to changes in the amount of heat required.

Modern hot water systems have a circulator which pumps the water through the piping system. The excellent heat absorption capability of water-backed boiler heat exchangers allows boilers to be compact. Piping and room heat exchangers can also be relatively small.

Hot water boilers are often controlled by boiler-mounted controls which maintain the boiler temperature within a preset range. Other systems use a thermostat control which cycles the boiler burners on and off whenever there is a demand for heat. The amount of heat transferred to the dwelling depends on the temperature and the amount of water which is circulated. The circulating pump is often controlled by the room thermostat and thereby regulates the temperature in the dwelling.

Hot water boilers are frequently categorized by the type heat exchanger, cast iron, fire tube or water tube. These heat exchanger variations are

BEST DOCUMENT AVAILABLE

detailed in Section 3 of this manual. Each style uses a water-backed heat exchanger to transfer heat from combustion to the water.

Boiler Structure And Operation

Modern hot water boilers designed for space heating are housed in sheet metal enclosures which protect operating components, control the flow of air for combustion, and enclose heated surfaces. The draft hood and vent connection are normally located at the top of the enclosure. A typical hot water boiler is shown in Figure 6-9.

Hot water outlet connections are normally at the top of the boiler; return connections are at the bottom. Since water expands when it is heated, some expansion volume is necessary in the circulation piping. An air-filled expansion tank is normally connected near the hot water outlet connection and located above the water level in the boiler. However, often an expansion tank is installed on the suction side of the circulating pump drain valve for draining the system.

The electric motor-driven circulating pump is usually located adjacent to the boiler on the return side of the piping system. In addition, a pressure relief valve guards against over pressure conditions.

Some hot water boilers are controlled by a boiler-mounted temperature control called a low limit or aquastat which cycles the burner to maintain a preset operating temperature in the boiler. A thermostat, in the conditioned space, controls the need for water flow to the radiators or coils by energizing the circulating pump. When the conditioned space temperature drops below the selected setting, the thermostat calls for heat and the circulating pump starts. Water flows to the radiators or coils, releases heat into the conditioned space, and returns to the boiler for reheating. The return circulating water lowers the boiler water temperature and the temperature control turns the main burners on.

When the conditioned space reaches the selected temperature, the thermostat stops the circulating pump. When the boiler reaches operating temperature, the aquastat turns off the gas supply to the main burner.

Other boilers, particularly the water tube-type, which do not have significant amounts of water in storage, activate only when the room thermostat calls for heat and the circulating pump is operating. If the boiler reaches the normal operating temperature, the main burner cycles off. The circulating pump continues to run as long as there is a demand for heat. This type of control system prevents main burners from operating during summer and other light load conditions.

The building where the hot water boiler is installed may have several thermostats, each controlling the temperature of a separate zone. Each thermostat may control a separate circulating pump but, more commonly, all thermostats operate a single pump and flow to each zone is controlled by an electrically-operated valve in the return line. "End switches" on the zone valves control the pump operation so that at least one zone must call for heat before the pump will run.

OPERATING COMPONENTS

Hot water boilers are equipped with a main gas manifold which connects to the gas supply piping, includes all gas controls, and distributes the gas to the main burners. Again, a manual gas cock is located between gas controls and supply piping. This allows shutoff of the gas supply for boiler servicing without shutting off the gas supply to other appliances. The gas manifold also includes a pressure regulator, automatic pilot safety valve, and main gas valve. On modern boilers, a combination gas valve replaces all of these devices and includes all required gas controls.

Operation of the main burner(s) in a hot water boiler is controlled by the main gas valve. This valve is in turn controlled by the thermostat and/or boiler-mounted limit controls as described later. It functions in a similar manner to the gas valve in a forced air heating system. However, some hot water boilers use modulating gas valves which throttle the main burner to a minimum flame.

Hot water boilers are also equipped with automatic safety pilot systems, which operate identically to similar heating systems discussed previously.

Boiler Temperature and Circulating Pump Controls

Water temperature controls and/or thermostats are the primary operating controls on a hot water boiler. These controls open and close the main gas valve, thus cycling the main burner on and off. They may also activate and deactivate the circulator.

In some arrangements, these controls only operate when the room thermostat calls for heat and the circulator pump is operating. In other boiler systems, temperature controls operate independently, maintaining boiler temperature within the normal operating range.

Most hot water boiler temperature controls are bimetal or diastat operated switches. These controls are installed directly into fittings or wells provided in the heat exchanger wall with the well immersed in boiler water. The switch assembly is normally accessible from outside the boiler cabinet to allow for adjustment, inspection, and maintenance. The switch assembly may have several sets of contacts arranged to provide low limit control, circulator pump control, and high limit control. Switches are of the differential-type. On some controls, the differential is adjustable.

BEST DOCUMENT AVAILABLE

Essentially, the term *aquastat* is used to describe a control switch which is activated by changes in water temperature. However, the term aquastat is also frequently used to describe a "*low limit* control". The low limit control is often used to control the boiler gas valve or otherwise maintain the temperature of the water within the boiler.

The circulator pump control is often incorporated into the low limit, however, it may also be an independent control. It usually only allows the circulator pump to operate when the boiler temperature is above a specific value and when the wall thermostat calls for heat.

The *high limit* control is a normally-closed switch which opens in an overheating condition. It is normally wired in series with the gas valve circuit so as to extinguish the main burners should a high temperature condition occur.

It is important to understand that there are many control variations for hot water boilers. Each system must be examined closely.

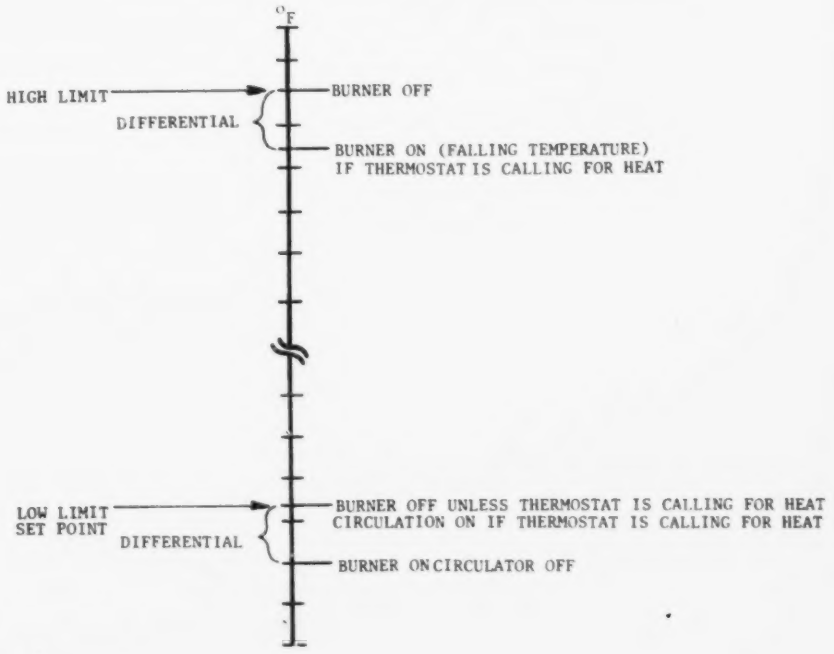
Figure 6-10 shows the control functions of a typical boiler temperature control. Typical set-point temperatures are shown. Boiler characteristics differ, therefore these functions and temperatures may be slightly different for a specific system.

When the boiler cools (Figure 6-11) below the low limit temperature set-point, the circulating pump control contacts open to prevent pump operation. The low limit control contacts close simultaneously to start main burner operation. When the boiler water temperature rises to the high temperature set-point, the low limit control contacts open. If the thermostat is calling for heat, the circulating pump will start. At this point, the main gas valve may be held open by the room thermostat. If the boiler water temperature reaches the high limit temperature control set-point, the main burner shuts off, and the circulating pump continues to operate. When the boiler cools to the high temperature set-point, the burner will operate again if the thermostat is calling for heat. When the demand for heat is satisfied and the room thermostat contacts open, the circulating pump will stop and the main burner will shut off. Control of the main burner is then normally returned to the low limit control until the room thermostat again calls for heat.

Improper temperature differential settings for controls may result in too frequent cycling of the main burner under light load conditions. Operating set-points and differentials should always be set to the values recommended by the boiler manufacturer. Set-points are adjustable on most controls—differential is adjustable on some. If controls malfunction, they are normally replaced rather than repaired.

FIG. 6-10

HOT WATER BOILER CONTROL FUNCTIONS



Boiler Water Level Controls

Water level controls are provided on many hot water boilers to maintain proper boiler water level. A low water cut-off safety control may also be provided to shut off the gas supply if water falls below a predetermined *minimum* operating level.

Water level controls on hot water boilers are float operated mechanical switches which monitor water level. Because the boiler water must be kept at the proper level, the controls are frequently located on the expansion tank. Construction of the boiler and the arrangement of the piping system ensure that all air in the system is directed to the expansion tank.

Water Distribution Controls

The circulating pump is the primary controller of water distribution to radiators or coils in the conditioned space. Control of this pump is closely related to the primary temperature control of the boiler (low limit,

BEST DOCUMENT AVAILABLE

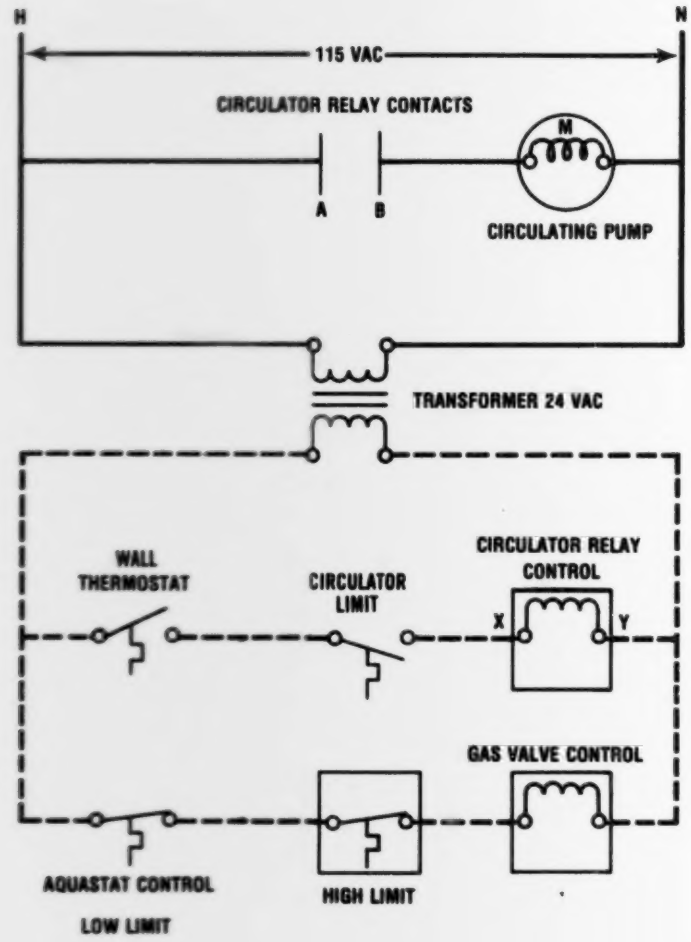
circulator control), as discussed earlier. Other controls in the water distribution system are manual shutoff valves and zone controls.

Manual shutoff valves are provided at each radiator or coil and at various other points in the piping system. These valves are used to isolate various sections of the system for maintenance. They may also be used to throttle off the flow of water to balance the heat delivery to various parts of the dwelling. Care must be taken not to throttle flow severely as pump damage can result.

Zone controls are another (and more effective) way to adjust the delivery of heat to various parts of the structure. With a zone control system, individual thermostats are located in various areas of the structure. Each thermostat controls an electrically-operated water valve on the return line of the zone piping system. If the thermostat for a particular zone is calling for heat, the appropriate valve is opened and water flows in the piping loop supplying hot water to the proper area. Since other zones may not be calling for heat, those valves remain closed.

FIG. 6-11

CONVENTIONAL HOT WATER BOILER (LADDER SCHEMATIC)



BEST DOCUMENT AVAILABLE

SECTION 7

ENERGY CONSERVATION COMPONENTS

ENERGY CONSERVATION

Previous sections within this manual cover conventional gas space heating fundamentals, components and systems. Generally, these systems were designed and manufactured during a period when fuel gases were in abundant supply and quite inexpensive. Space heating appliance efficiency was less of a concern than appliance dependability, simplicity and ease of installation.

Today, the conservation of *all* energy has become a necessary part of our lifestyle. Currently, both the supply and cost of energy, point toward the good sense and cost effectiveness of conservation.

Space heating, in itself accounts for over 67% of typical residential energy consumption. Because space heating ranks high in energy usage, energy conserving components have been developed for use on both new and existing gas space heating appliances. For example, automatic set-back wall thermostats are well documented as a cost effective conservation component. Obviously, in the heating season, whenever the temperature setting of the wall thermostat is decreased, energy is conserved. Whether this is accomplished manually or automatically, the result is the same . . . . a savings.

The balance of this manual is devoted to two other types of energy conserving components . . . vent dampers and intermittent ignition systems.

Vent Dampers

The vent damper is simply an automatically controlled baffle which is located in the vent of a gas appliance. It automatically opens during the appliance "on" cycle and automatically closes during the appliance "off" cycle.

During the "on" cycle, vent dampers have absolutely no effect on appliance operation or energy savings. However, during the "off" cycle, vent dampers minimize the amount of heat loss from the appliance and from the appliance space.

Intermittent Ignition Devices

The intermittent ignition device is an automatic "system" which eliminates the need for a *constant* pilot burner. The "IID" *both* cycles "on" *and* ignites the pilot *only* when there is a call for heat.

Like the vent damper, the IID conserves energy during the appliance "off" cycle. It has absolutely no effect on normal appliance operation or energy savings during the "on" cycle.

Qualifying the Appliance Installation

From the previous explanation, it is plain to see that both vent dampers and IID's conserve energy. However, one must objectively determine if the cost of installing a vent damper or an IID is justified by the energy saved.

This decision is primarily dependent on the age, condition and location of the space heating appliance. In addition, it is dependent on the cost and availability of fuel, and the weather conditions existing in the area. Each installation must be considered separately.

For example, appliances located in spaces where the temperature is considerably higher than outdoors may be prime candidates for the installation of vent dampers. On the other hand, appliances located in geographical areas which have moderate temperatures may be prime candidates for the installation of IID's.

In many cases, the existing space heating appliance may have many years of useful service before system replacement becomes necessary. These appliances may be prime candidates for the installation of vent dampers and/or ignition devices. On the other hand, space heating appliances which are outdated or, are unsafe are prime candidates for system replacement.

Before you can adequately determine if a particular space heating appliance is even a candidate for these conservation components, you must perform a "pre-installation inspection" . . . more commonly called a "pre-inspection" or "safety inspection."

BEST DOCUMENT AVAILABLE

The pre-inspection is important and must be performed in a thorough and conscientious manner. If the appliance fails any part of the pre-inspection and you determine that a condition exists which could result in unsafe operation, the appliance must be shut down. The owner and local authority must then be notified of the required repairs. After the repairs are made, the pre-inspection can be completed.

Required Tools and Equipment

Before beginning the pre-inspection, collect all of the necessary tools and reference material. Some or all of the following may be required.

1. CO Detector.
2. Flue Gas Thermometer.
3. Manometer or pressure gauge.
4. Appliance manifold adaptor fitting.
5. Orifice drill kit.
6. Orifice sizing tables.
7. Appropriate wrenches.
8. Appropriate screwdrivers.
9. Matches.
10. Flashlight.
11. Inspection mirror.
12. Tape measure.
13. Bubble leak detector.
14. Electronic leak detector (optional).
15. Vent sizing tables.
16. NFPA #54 or local code book.

PRE-INSPECTION

The appendix of the National Fuel Gas Code (ANSI Z 223.1, NFPA #54) details the recommended guidelines for performing a "Safety Inspection". The Federal Register, Vol. 45, No. 187, Sept. 24, 1980, in Section 456.914 details the specific procedure in performing a "Pre-Installation Inspection", which follows is a combination of these two procedures. All 16 (sixteen) steps must be followed if a vent damper or vent damper and IID are being installed by an individual who is participating in the U.S. Department of Energy's RCS (Residential Conservation Service) Program. If you are not participating in the RCS program, *only* those steps which are preceded by an asterisk *must* be performed. In addition, if only an IID is being installed, *only* those steps preceded by an asterisk *must* be performed.

The following is a list of the steps which are included in the Pre-Inspection Procedure:

STEP 1 - Perform a check for the presence of CO and combustible gas.

STEP 2 - Check applicable codes and regulations.

*STEP 3 - Conduct a gas leakage test.

*STEP 4 - Inspect the venting system.

STEP 5 - Inspect the termination of the vent.

STEP 6 - Inspect the wall thermostat.

*STEP 7 - Inspect burners and size orifices for BTU input.

*STEP 8 - Check burner operation and make any required adjustments.

*STEP 9 - Check for adequate ventilation and combustion air.

STEP 10 - Check the electrical wiring and components.

*STEP 11 - Inspect the heat exchanger.

*STEP 12 - Conduct a spillage test.

STEP 13 - Measure the CO content and temperature of the flue gases before the draft hood.

STEP 14 - Measure the flue gas temperature after the draft hood.

*STEP 15 - Recheck appliance operation.

*STEP 16 - Test the appliance operating controls and safety components.

Pre-Inspection Procedure

STEP 1 - Perform a Check for the Presence of CO and Combustible Gas.

The first step in performing the pre-inspection is to ensure that the area in which the appliance is located is free of gas leaks and harmful concentration of CO. The check for combustible gas can be accomplished by the use of a meter which measures the percentage of combustible gas mixed in the air. The absence of combustible gas is indicated by a reading of less than 20 percent of the lower explosive limit.

If a meter is not available, a "smell" test may be performed which will indicate the presence or absence of an odorized fuel gas. However, if you have any physical restrictions, such as a common cold, it is advisable to use a test meter.

BEST DOCUMENT AVAILABLE

If your check indicates that a gas leak is *present*, locate the source of the leak, and if possible, correct it. Otherwise, close the shutoff valve at the meter, evacuate the building, and notify the utility or the gas supplier.

The second part of this step is a check for a harmful concentration of CO in the vicinity of the appliance. This check should be made in the general area where the appliance is installed. The absence of carbon monoxide or CO is indicated by a reading of less than 50 parts per million.

STEP 2 - Check Applicable Codes and Regulations.

This step in the pre-inspection is performed in order to make certain that the heating system has been installed in accordance with applicable codes and regulations. The heating system installation should at least meet the minimum requirements of the National Fuel Gas Code (ANSI Z223.1 or NFPA Pamphlet #54).

STEP 3 - Conduct a Gas Leakage Test.

Next, a gas leakage check must be performed on the appliance piping and control system downstream from the appliance shutoff valve. There are several points that you need to remember.

You must monitor the pressure for at least *three minutes*. If there is no noticeable drop in pressure during this period, the piping is free of gas leaks. If the pressure drops, you must locate the leak and repair it *before* you can continue with the inspection.

Two safe methods for locating a gas leak are an electronic leak detector or a commercially available bubble leak solution. It is important to remember that matches, open flames or other sources of ignition should never be used to locate the source of a leak.

STEP 4 - Inspect the Venting System.

The fourth step requires an inspection of the venting system to determine whether or not the vent was properly sized and whether any damage or deterioration has occurred. Information on venting and ventilation is detailed in Section 3, however, there are several key points that you need to remember.

Distance From Combustible Materials

Single wall pipe must be located at least 6 inches from any combustible materials. Single wall pipe cannot be installed in a concealed space or an unoccupied attic and it also may not pass through any attic, inside wall or floor. Double wall type "B" vents can be located from 1 to 3 inches from combustible materials depending on the type of pipe material used. Always check manufacturers' specifications for exact distances.

Vent Sizing

To quickly check the size of the vent, you can use the alternate method which is discussed in Section 3 of this manual, as well as in NFPA #54. Remember, when using the alternate method, the cross-sectional area of the vent connector should not be less than the area of the draft hood outlet. If you are sizing a common vent, the area of the common vent should be equal to or larger than the area of the largest vent connector plus 50 percent of the area of any smaller connector(s).

If you have followed this procedure and the individual or combined vent is not of adequate capacity, refer to the vent sizing tables in NFPA #54.

Pitch of Slope of Vents

Gas vents must be installed so that the lateral runs slope upward at least 1/4 inch per foot. Remember downward slopes in the lateral runs decrease the flow of flue gases and can allow them to spill out of the draft diverter.

Water Leaks, Clearance, Appearance

Now that you have determined that the space heating appliance venting system is constructed of approved materials, is properly sized and is installed with sufficient pitch or slope, you must determine that the venting system is free of blockage, restrictions, leakage, and corrosion which could cause an unsafe condition. This is determined by a visual inspection of the *entire interior* of the venting system. While you are making this visual inspection, also make certain that there are no manually adjustable dampers in the vent system.

In some cases, you may not be able to perform an internal visual inspection. In this case, any spillage test that you perform can *only* be done when the outdoor temperature is above 65°F and when the wind velocity is less than 10 miles per hour.

STEP 5 - Inspect the Vent Termination.

The final step in inspecting the venting system is to make certain that the vent terminates at least 2 feet above the point where it exits the roof and at least 2 feet higher than any portion of the building within a horizontal distance of 10 feet or otherwise according to manufacturer's instructions. If a gas appliance vent terminates into a masonary or factory-built chimney, make certain that any fireplace opening is permanently sealed.

STEP 6 - Inspect the Wall Thermostat

Next, determine that the thermostat(s) are operating properly. Examine *each* wall thermostat for signs of physical damage as well as dust,

BEST DOCUMENT AVAILABLE

corrosion, pitted contacts, cracked or broken base or housing, and insects. The heat anticipator should be properly adjusted. Finally, make certain that the thermostat is located on an inside wall within an average temperature zone with good ventilation.

STEP 7 - Inspect Burners and Size Orifices for BTU Input.

The next step in the pre-inspection is to determine that there is no blockage or corrosion of the main burners. Then, size the orifices and determine the manifold pressure. Go to the appropriate orifice sizing chart and compute the appliance input. If the input is in excess of the rating listed on the data plate, make the necessary changes to reduce it.

If an additional or redundant gas valve is being installed, note the pressure so that the appliance regulator of the replacement gas valve can be adjusted to that of the previous gas valve.

STEP 8 - Check Burner Operation and Make Any Required Adjustments.

While the appliance is in operation, observe the main burner flame. Cycle the main burner several times by turning the main power switch "on" and "off". If the appliance is equipped with flame modulation, check the main burner at low and high flame. Look for evidence of improper burner alignment, combustion product leakage, improperly adjusted pilot, etc. If the flame characteristics are abnormal, or ignition is "rough", correct the problem.

STEP 9 - Check for Adequate Ventilation and Combustion Air.

Next, you need to determine that there is adequate air supply for both combustion and ventilation. The air for ventilation may be provided from a ventilated crawl space or attic, from within the building or directly from outdoors. Regardless of the source, at least two openings are required for proper ventilation; one near the top and one near the bottom of the appliance space. Permanent openings connected with the outdoors must have at least one square inch of free area for each 5,000 Btu an hour input for each appliance.

Remember that the actual size of the ventilation openings will depend on three factors:

1. The Btu input of the appliances.
2. The source of ventilation (indoor or outdoor).
3. The type of louver or grill.

STEP 10 - Check the Electrical Wiring and Components.

First, shut off the electricity to the heating appliance and inspect the fuses or circuit breakers and main wiring to make certain that they are the correct size for the appliance. Then, check the electrical wiring on the appliance to ensure that there are no loose connections, charred, cracked, or worn insulation or potential shorting to ground. Repair or replace wiring or connections, where necessary.

STEP 11 - Inspect the Heat Exchanger.

The next step is to inspect the heat exchangers. The procedure will vary depending on the appliance (i.e. forced air heating system or hot water boiler).

To inspect the exchanger on a forced air heating appliance, either dismantle the appliance and use an inspection mirror and light to check for cracks, openings, and excessive corrosion. Other alternate methods for checking the heat exchanger include a CO and CO_2 test, smoke bombs, salt and peppermint tests.

In checking the heat exchanger of a hot water boiler, you should check the surrounding area carefully for signs of water leakage or evidence of rust and corrosion. Determine that air supply vent has no flammable materials or materials that could emit toxic fumes on being heated.

STEP 12 - Conduct a Spillage Test.

The next step in performing the pre-inspection is to perform a draft hood spillage test. In this test, we want to create the worst venting conditions that may reasonably occur by ensuring that the appliance space is at its lowest pressure. This condition is created by closing all building outside doors and windows. Then, turn on exhaust fans at maximum speed such as the range hood, bathroom exhausts, and any other exhaust fans that may be applicable.

Turn on any clothes dryers that are vented to the outside. *Do not operate a summer exhaust fan.* If a fireplace exists, make sure that there is no fire in the fireplace and that the fireplace dampers are closed.

Remember, if the interior of the venting system was not visually inspected, you can only perform the spillage test when the outside temperature is above 65°F and the wind velocity is below 10 miles per hour.

Now, place the space heating appliance in operation. At 2 minutes of main burner operation, test for spillage at the draft hood relief opening with a lit match or cigarette. Make certain that you can clearly determine the flow of smoke. After testing for spillage at the heating appliance draft hood, also test for spillage at any other draft hood that is shared by the same common vent.

BEST DOCUMENT AVAILABLE

Shut the heating appliance down and wait 15 minutes for the vent to cool down. Then, turn on all the other gas appliances that operate on the same venting system or those which operate in the same room as the heating appliance. Repeat the spillage test on each appliance after 2 minutes of main burner operation.

STEP 13 - Measure the CO Content and Temperature of the Flue Gases before the Draft Hood.

After 5 minutes of main burner operation, measure the flue gas temperature and carbon monoxide concentration. This measurement will be taken at a point one inch before the inlet to the draft hood in the center of the flue passage.

The flue gas temperature at this point must be at least 200°F to limit condensation within the vent. If the heating appliance is a candidate for a vent damper, the temperature at this point also must not exceed 550°F.

Now, test for carbon monoxide. The maximum allowable carbon monoxide concentration for this test is .04 percent or 400 parts per million.

If the heating appliance is equipped with a modulating gas valve, perform the flue gas temperature and the CO test at both the maximum and minimum flame conditions.

STEP 14 - Measure Flue Gas Temperature After The Draft Hood.

The next step is to measure the flue gas temperature six inches above the draft hood outlet. This step is only necessary if you are installing an electrical or thermal vent damper. A flue gas temperature of *at least* 370°F is required for a thermal vent damper and 375°F for an electrical vent damper with a damper closing temperature control.

To make the test, first, drill a hole in the vent connector large enough to accommodate the probe of a test thermometer. Insert the thermometer into the hole. After five minutes of main burner operation, record the temperature. Remember a vent damper cannot be installed if the flue gas temperature exceeds 550°F. After the flue gas temperature has been measured, seal the hole in the vent connector.

STEP 15 - Recheck Appliance Operation.

You are now ready to recheck the appliance operation. Return the doors, windows, exhaust fans, fireplace dampers and other appliances to their normal condition. With the appliance operating, determine that the pilot burner is satisfactorily igniting the main burner by turning the main power switch "on" and "off." Ensure that the pilot safety device blocks the flow of gas to the main burner when the pilot burner has been extinguished. If the shutoff or drop out time of the pilot safety is not known for the particular appliance, use a safety shutoff time of one minute.

STEP 16 - Test the Appliance Operating Controls and Safety Components.

The final step in completing the pre-inspection is to check the control and safety components to ensure that they are operating as specified by the manufacturer's instructions.

For forced air heating systems, check the fan and limit to determine that they are operating within the manufacturer's specifications. If you are inspecting a hot water boiler system, test any low water cutoffs, automatic feed controls, high-pressure limit controls, high-temperature limit controls, relief valves, water pumps, and the circulating system.

You have now completed all the steps required for a pre-inspection. If there are areas in which you feel that you need additional information, refer back to the applicable sections of this manual as well as NFPA #54.

VENT DAMPERS

As previously stated, the vent damper is an automatically controlled baffle which is located in the vent of the space heating appliance. It opens during the appliance "on" cycle and closes during the "off" cycle. It conserves energy in two different ways.

First, the vent damper minimizes the loss of "residual heat" from the appliance. Residual heat is the potentially useful heat which remains in the appliance at the end of the "on" cycle. This heat is normally lost up the vent during the "off" cycle. However, when a vent damper is installed, the loss is minimized since the damper baffle is closed during the "off" cycle (see Fig. 7-1A and B).

Second, the vent damper minimizes the loss of heated air from the appliance space. Appliances which are located in spaces which are *not* open to the outdoors are typically at temperatures well above the outdoors. This is especially true when the space heating appliance is located in a "conditioned air space". Again, the heated air is normally lost up the vent, however, the loss is minimized with the use of a vent damper (see Fig. 7-2A and B).

Basic Structure and Operation

There are three different categories of vent dampers: *thermal*, *electrical* and *mechanical*. The category of vent damper is determined by the force used to open or close the baffle. Each type performs its function in a different manner, although all types accomplish the same end result.

BEST DOCUMENT AVAILABLE

FIG. 7-1A

CONVENTIONAL FURNACE

RESIDUAL HEAT LOSS

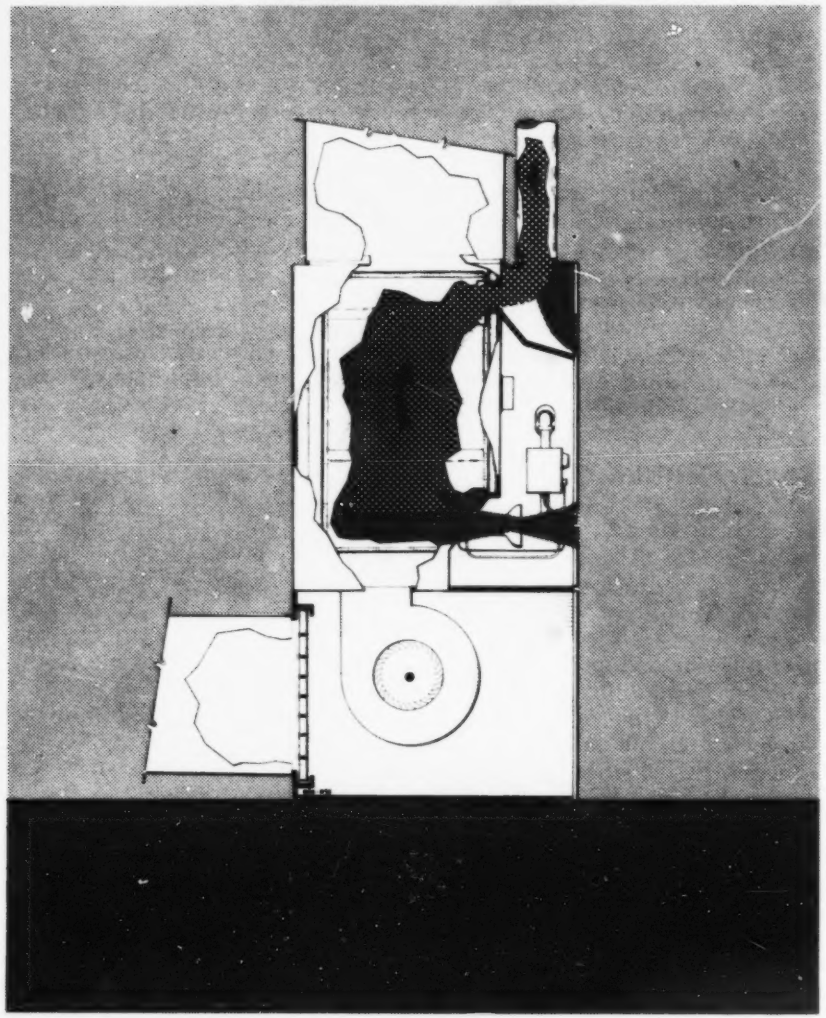
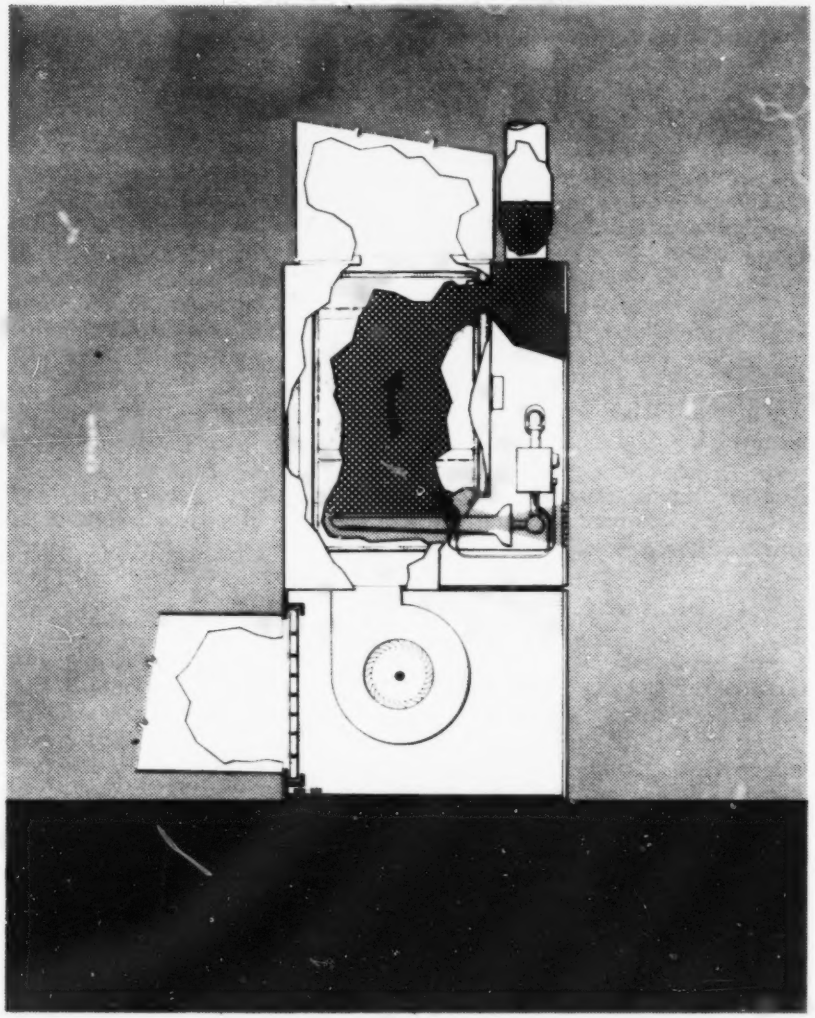


FIG. 7-1B

MODIFIED CONVENTIONAL FURNACE

RESIDUAL HEAT SAVED



The basic vent damper consists of a round or oval collar which is installed between the appliance draft diverter or draft hood and the vent connector. A baffle, located within the collar, is activated either by a thermal, electrical or mechanical device. Thermally operated vent dampers typically use bimetals to open and close the baffle. Electrically operated vent dampers use an electric motor, solenoid and/or return spring to open and close the baffle. Mechanically operated vent dampers use some type of gas pressure operated diaphragm to open and close the baffle. Currently, no firms produce an approved mechanical vent damper. For this reason only thermal and electrical vent dampers will be covered in this manual.

BEST DOCUMENT AVAILABLE

FIG. 7-2A

CONVENTIONAL FURNACE

CONDITIONED AIR LOSS

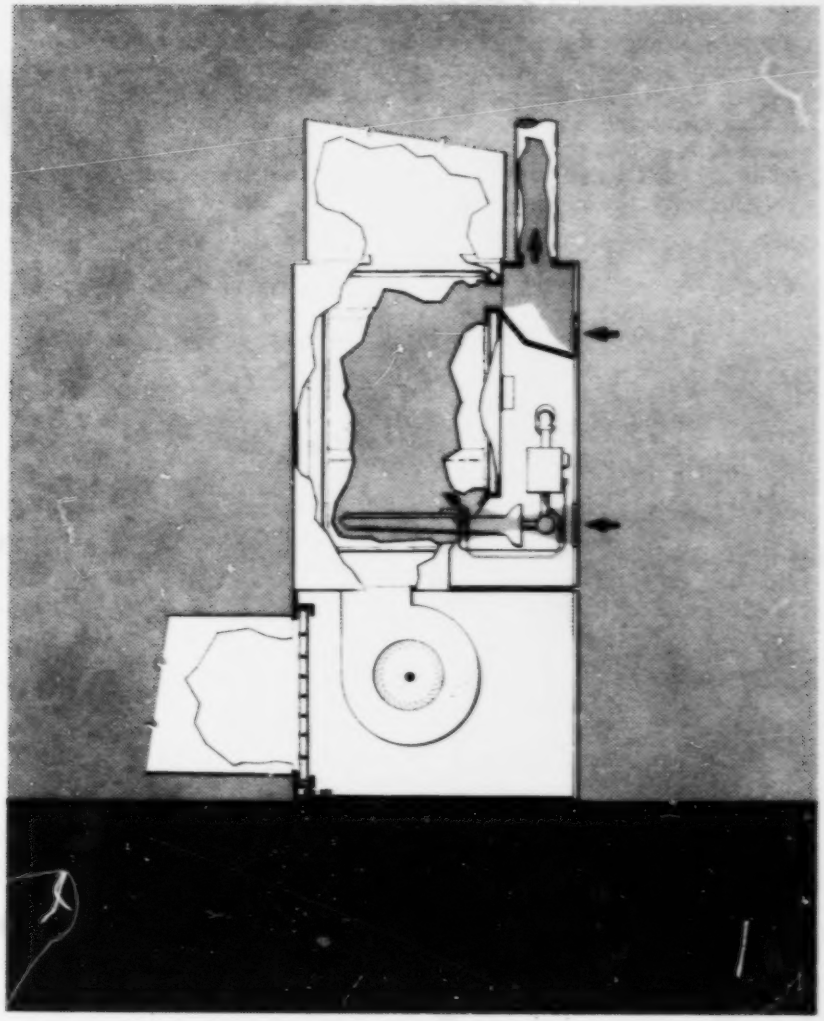
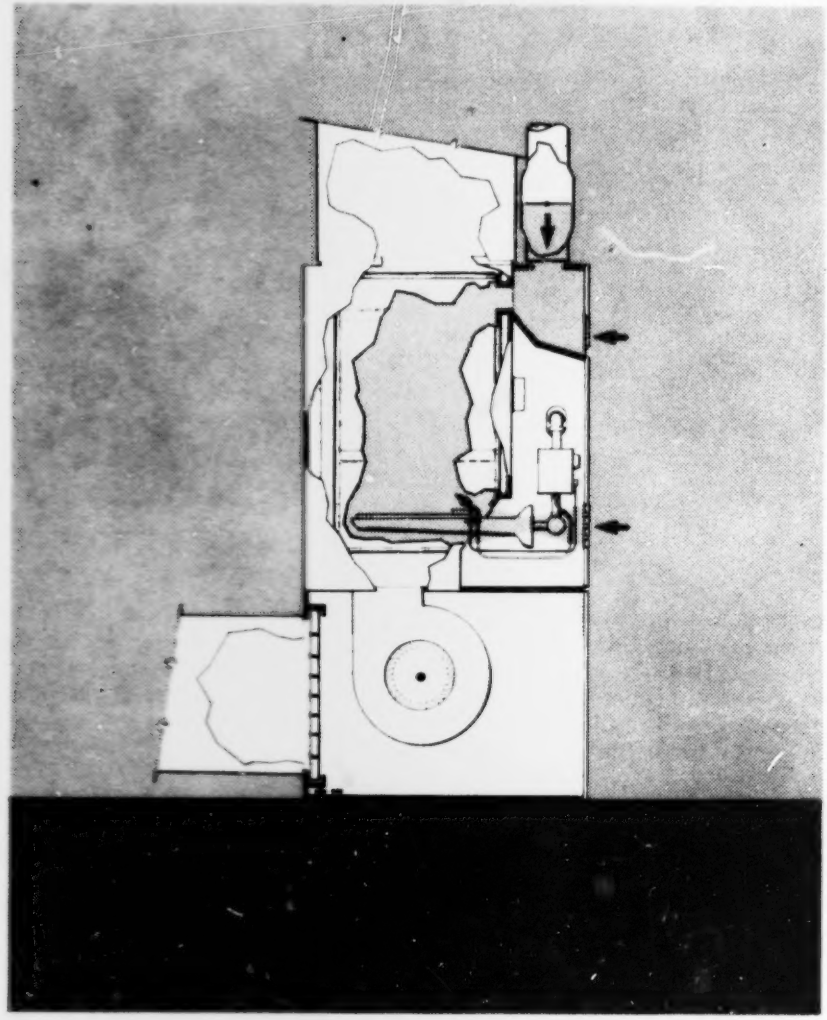


FIG. 7-2B

MODIFIED CONVENTIONAL FURANCE

CONDITIONED AIR SAVED



Thermal Vent Dampers

The simplest type vent damper is the thermal type. Thermal vent dampers use flat, watch spring or helix shaped bimetals to open the baffle. When the vent damper shown in Figure 7-3 is exposed to heated flue gases, the watch spring bimetal rotates, opening the baffle. As the bimetal cools, it closes the baffle. One of the major advantages of thermal dampers is that they operate independently of any electrical supply. Since thermal vent dampers operate totally on a "thermal principle", they have a built-in "fail safe" feature. For example, if during the "on" cycle, the main gas valve

BEST DOCUMENT AVAILABLE

FIG. 7-3

malfunctions and continually allows gas to flow to the main burners, the thermal vent damper will remain open.

Perhaps the only disadvantage to the use of the thermal dampers is the speed in which they open. Because they operate totally on a thermal principle, they are somewhat slow acting. For this reason, thermal vent dampers may cause slight spillage at the draft diverter when the main burners initially cycle "on". However, after a very short time, the bimetals fully open the baffle and spillage immediately stops.

Electric Vent Dampers

The electric vent damper is somewhat more complex than the thermal type (see Figure 7-4). The major variation between electric vent dampers is the electrical components used to open and close the baffle. Some models use an electric motor to open and close the baffle. Other models use an electric motor or solenoid to close the baffle and a return spring to open it.

In addition to these differences, electric vent dampers also use various types of interlock devices which under normal conditions prevent the main gas valve from cycling "on" until the baffle is fully open. This is commonly accomplished by the use of a normally open, mechanical "end switch" which completes a circuit to the gas valve *only* when the damper is fully open.

Because of the differences in electric vent dampers, it is impossible to detail each specific type. For this reason, a *generic* electric damper schematic is shown in Figure 7-5. Although this schematic shows a 24 volt model, vent dampers are also available for use with 115 volts.

With the thermostat in the "off" position, a circuit is completed from the 24 volt supply, through the normally closed contact (R_1) of the relay (R) and to the vent damper motor. The motor powers the baffle to the closed position. When the thermostat (TH) contacts close, the circuit is completed to relay (R). This opens the relay contacts (R_1) allowing a spring to return the damper to the open position. When the damper fully opens, it closes a mechanical "end switch" thereby completing the circuit from the 24 volt supply, through the appliance high limit switch and to the gas valve.

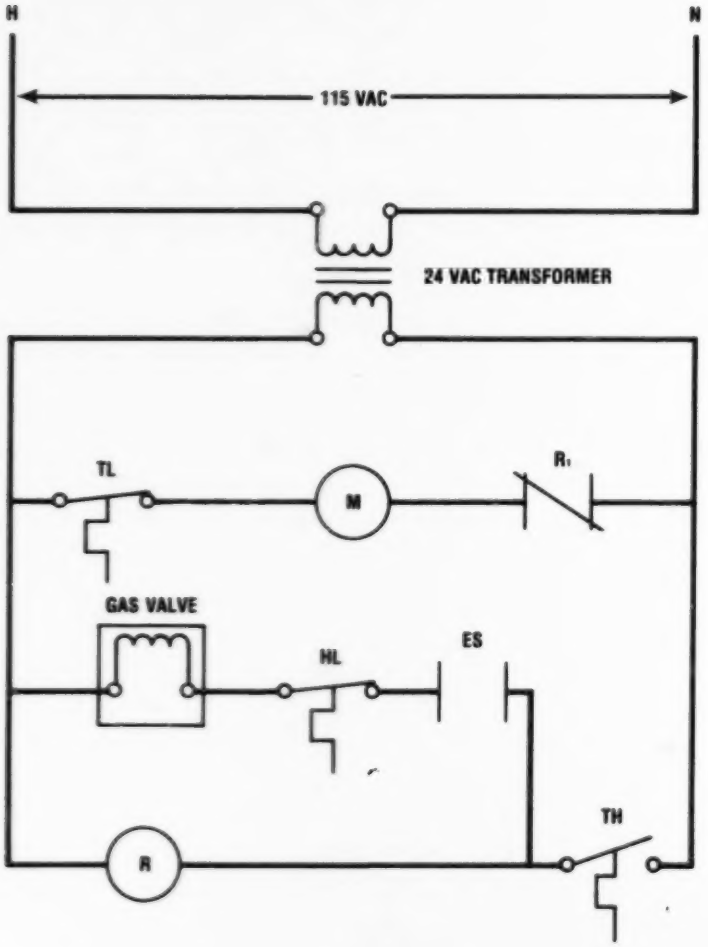
FIG. 7-4

BEST DOCUMENT AVAILABLE

Again, this is a basic schematic and is not representative of all electric dampers. When installing a vent damper, follow all manufacturer's instructions and wiring schematics.

FIG. 7-5

ELECTRICAL VENT DAMPER



SELECTING VENT DAMPERS

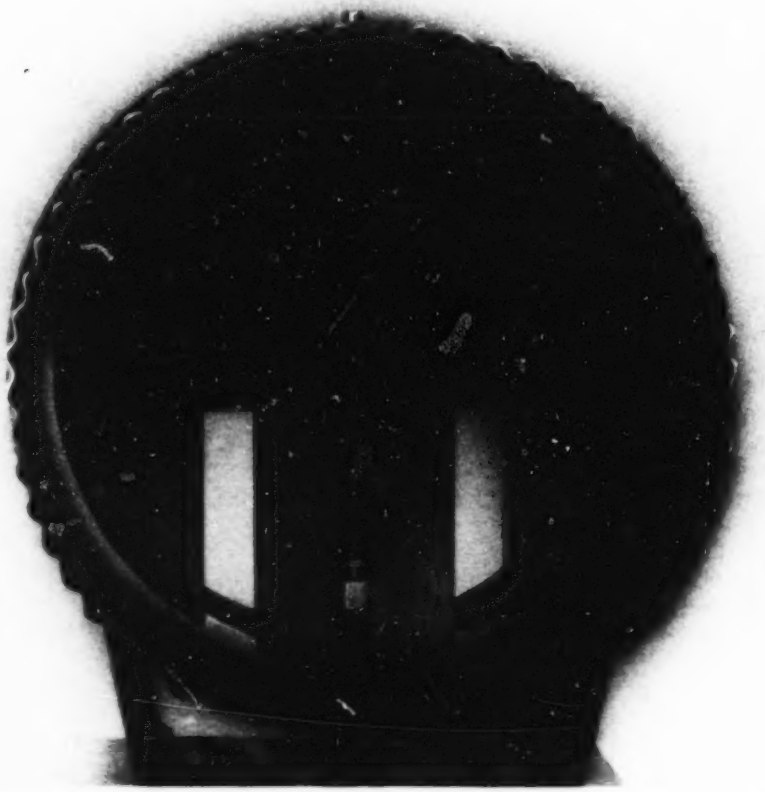
"Approved" vent dampers which are properly installed are safe and efficient. However, the *safety* of the overall installation rests in the hands of the installer. One of the most critical aspects of the installation is selecting the proper vent damper.

The design of the vent damper affects whether it can be installed independent of other components or whether other components must be used in conjunction with the vent damper. There are two major design features which affect this decision: the minimum internal free or open area of the vent damper and whether the vent damper uses an integral damper-closing temperature control.

Internal Free Venting Area

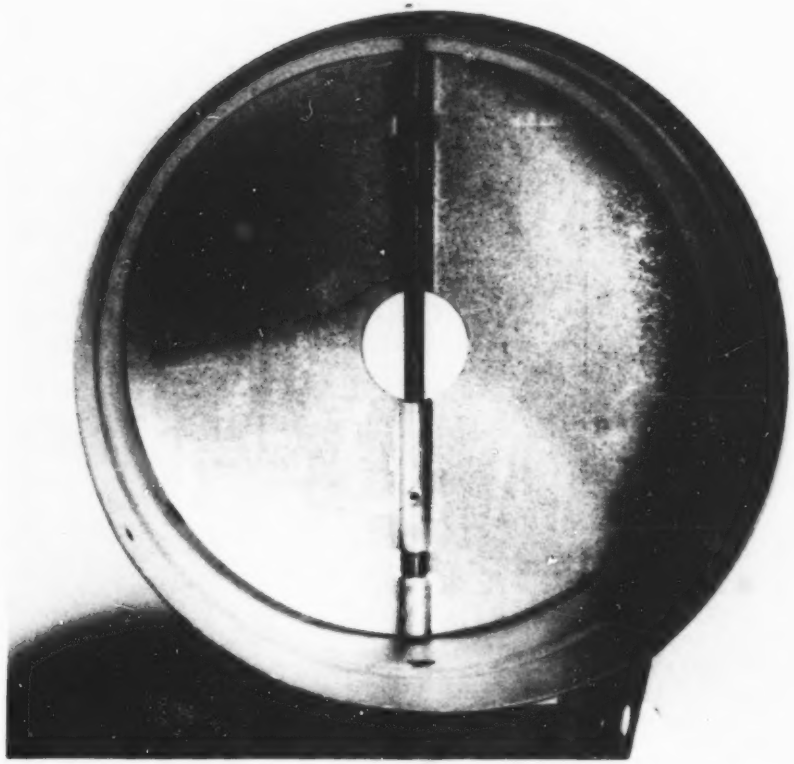
The two vent dampers shown in Figure 7-6A and B are in the closed position. However, neither of the baffles *completely* block the damper

FIG. 7-6A



BEST DOCUMENT AVAILABLE

FIG. 7-6B



opening. The vent damper in Figure 7-6A has an opening which is *greater* than 10% of the outlet or free venting area while the vent damper in Figure 7-6B has an opening which is less than 10% of the outlet or free venting area. This important difference will be covered in detail in the selection procedure for vent dampers.

Integral Damper Closing Temperature Control

Some *electric* vent dampers use a damper-closing temperature control which ensures that the vent damper is open when the flue gas temperature exceeds a specific level. This control is attached directly to the vent damper (see Figure 7-7). The damper control is basically a temperature operated normally closed switch which opens at 225°F.

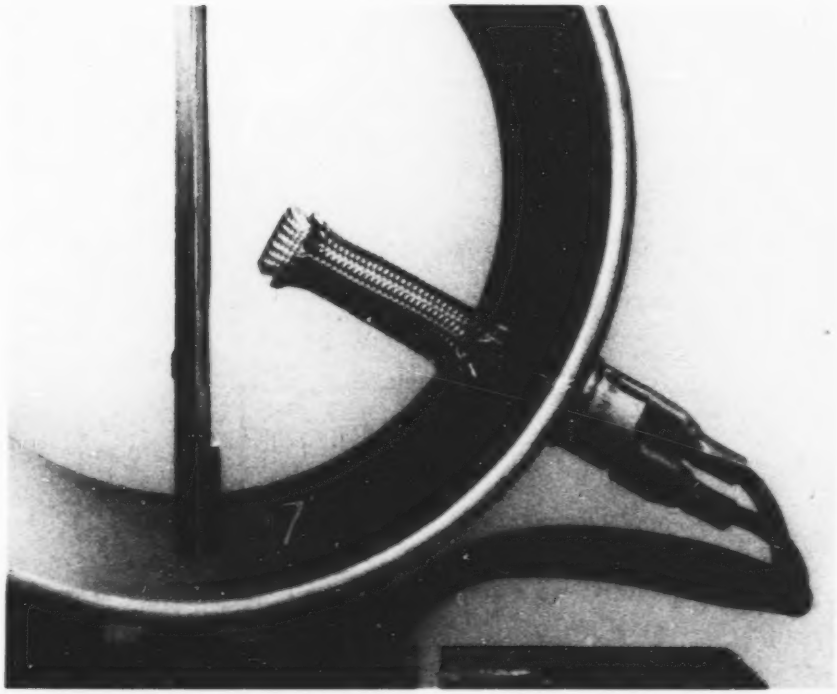
In the basic electric vent damper schematic in Figure 7-5, the damper closing temperature control would be located in the series circuit to the vent damper motor. In this example, regardless of the position of the relay contacts, whenever the flue gas temperature is above 225°F the contacts of the damper closing temperature control are open and the vent damper remains open. Again, the use of a damper-closing temperature control is an important feature which will be covered in detail in the selection procedure for vent dampers.

Additional Gas Valves and Redundant Gas Valves

In addition to the two previous important design features, another factor which affects the selection of the vent damper is whether the space heating appliance uses an additional gas valve or redundant gas valve. Solenoid gas valves and redundant gas valves are detailed in Section 5 of this manual.

Recall that the logic behind using two gas valves is to provide a "backup" if one of the valves fail due to such problems as trash in the gas supply. The use of an additional gas valve or a redundant gas valve almost completely eliminates the possibility of gas flowing to the main burner during the appliance "off" cycle.

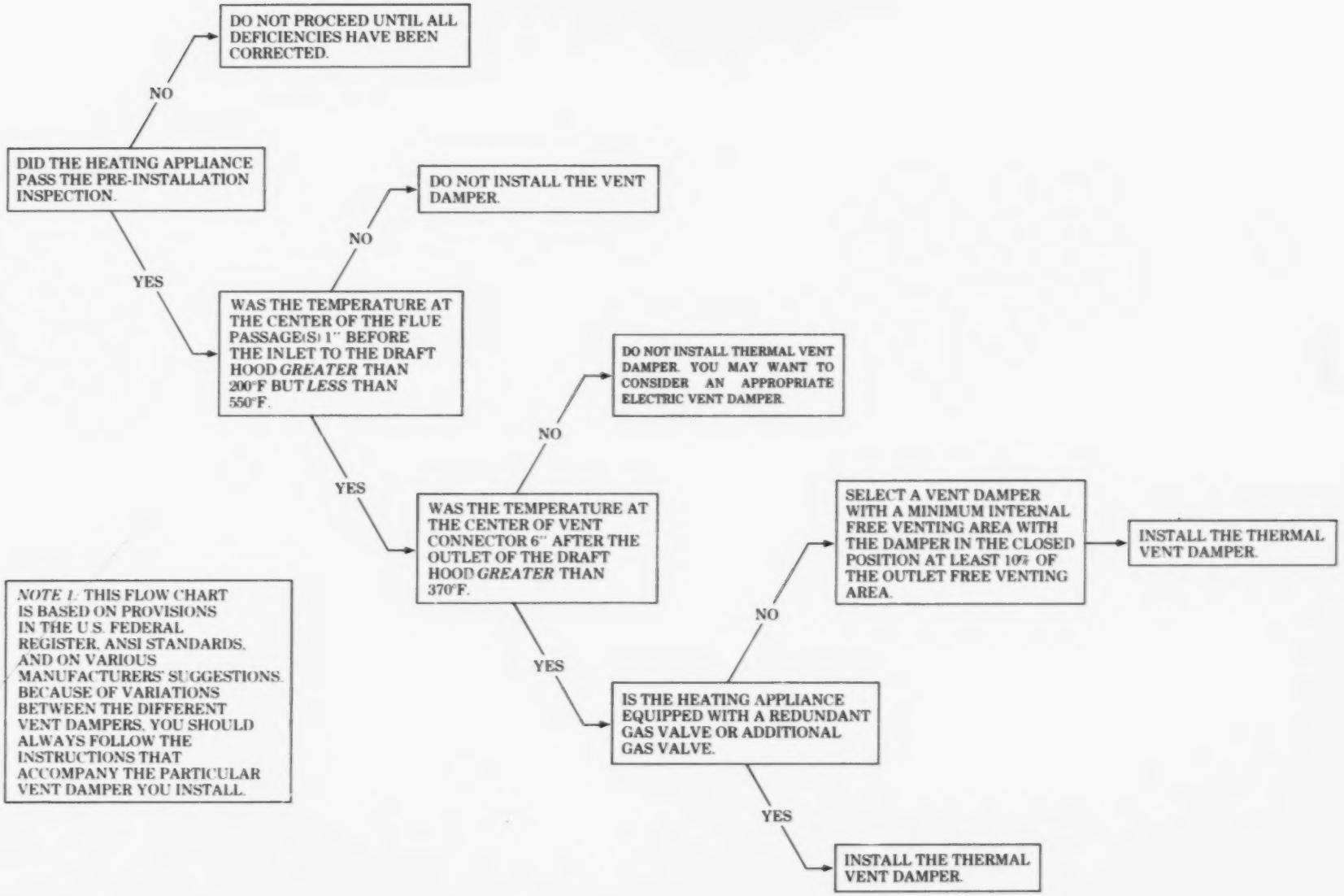
FIG. 7-7



BEST DOCUMENT AVAILABLE

FIG. 7-8

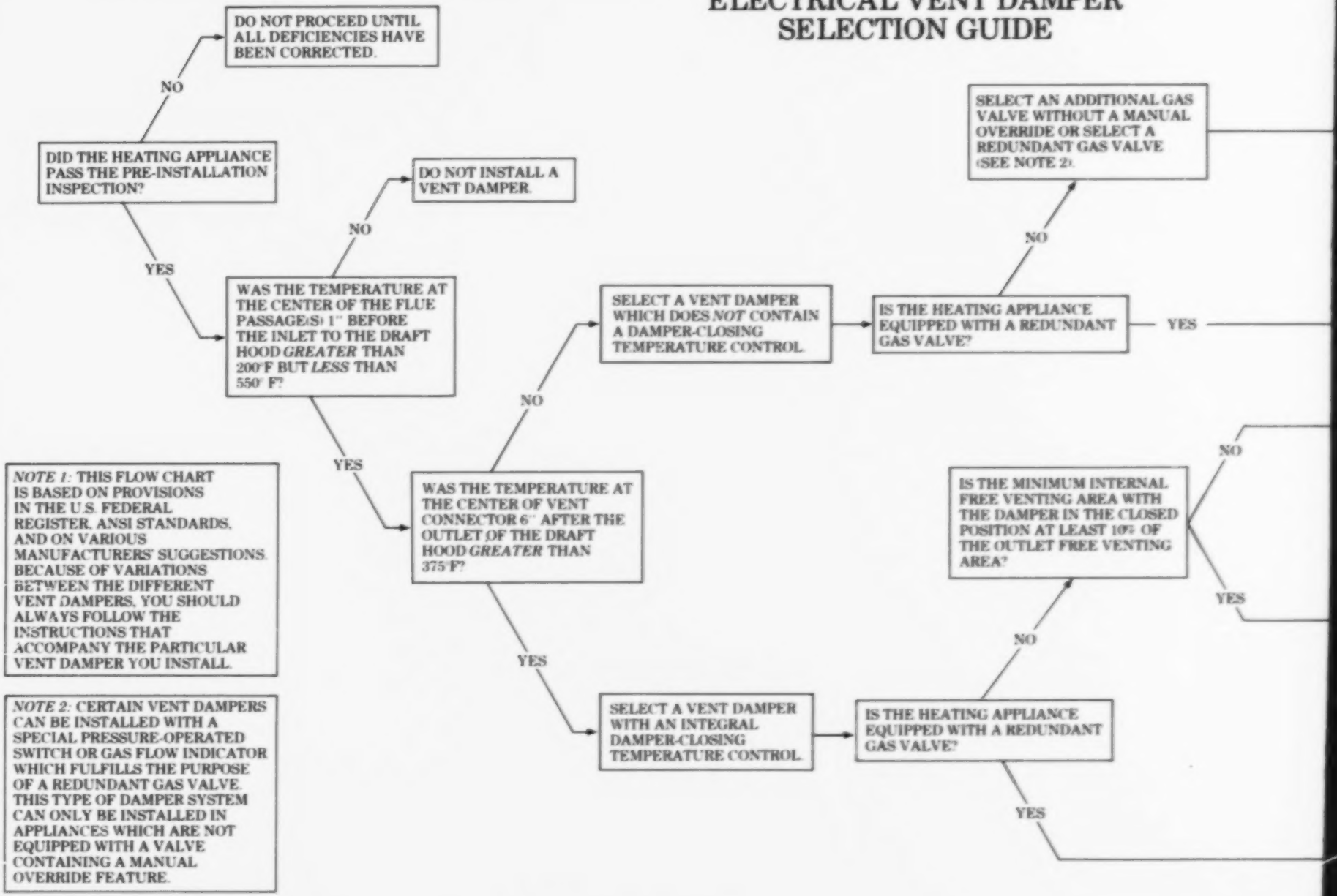
THERMAL VENT DAMPER SELECTION GUIDE


DID THE HEATING APPLIANCE PASS THE PRE-INSTALLATION INSPECTION.
NO
DO NOT PROCEED UNTIL ALL DEFICIENCIES HAVE BEEN CORRECTED.
YES
WAS THE TEMPERATURE AT THE CENTER OF THE FLUE PASSAGE(S) 1" BEFORE THE INLET TO THE DRAFT HOOD *GREATER* THAN 200°F BUT *LESS* THAN 550°F.
NO
DO NOT INSTALL THE VENT DAMPER.
YES
WAS THE TEMPERATURE AT THE CENTER OF VENT CONNECTOR 6" AFTER THE OUTLET OF THE DRAFT HOOD *GREATER* THAN 370°F.
NO
DO NOT INSTALL THERMAL VENT DAMPER. YOU MAY WANT TO CONSIDER AN APPROPRIATE ELECTRIC VENT DAMPER.
YES
IS THE HEATING APPLIANCE EQUIPPED WITH A REDUNDANT GAS VALVE OR ADDITIONAL GAS VALVE.
NO
SELECT A VENT DAMPER WITH A MINIMUM INTERNAL FREE VENTING AREA WITH THE DAMPER IN THE CLOSED POSITION AT LEAST 10% OF THE OUTLET FREE VENTING AREA.
INSTALL THE THERMAL VENT DAMPER.
YES
INSTALL THE THERMAL VENT DAMPER.
NOTE 1: THIS FLOW CHART IS BASED ON PROVISIONS IN THE U.S. FEDERAL REGISTER, ANSI STANDARDS, AND ON VARIOUS MANUFACTURERS' SUGGESTIONS. BECAUSE OF VARIATIONS BETWEEN THE DIFFERENT VENT DAMPERS, YOU SHOULD ALWAYS FOLLOW THE INSTRUCTIONS THAT ACCOMPANY THE PARTICULAR VENT DAMPER YOU INSTALL.

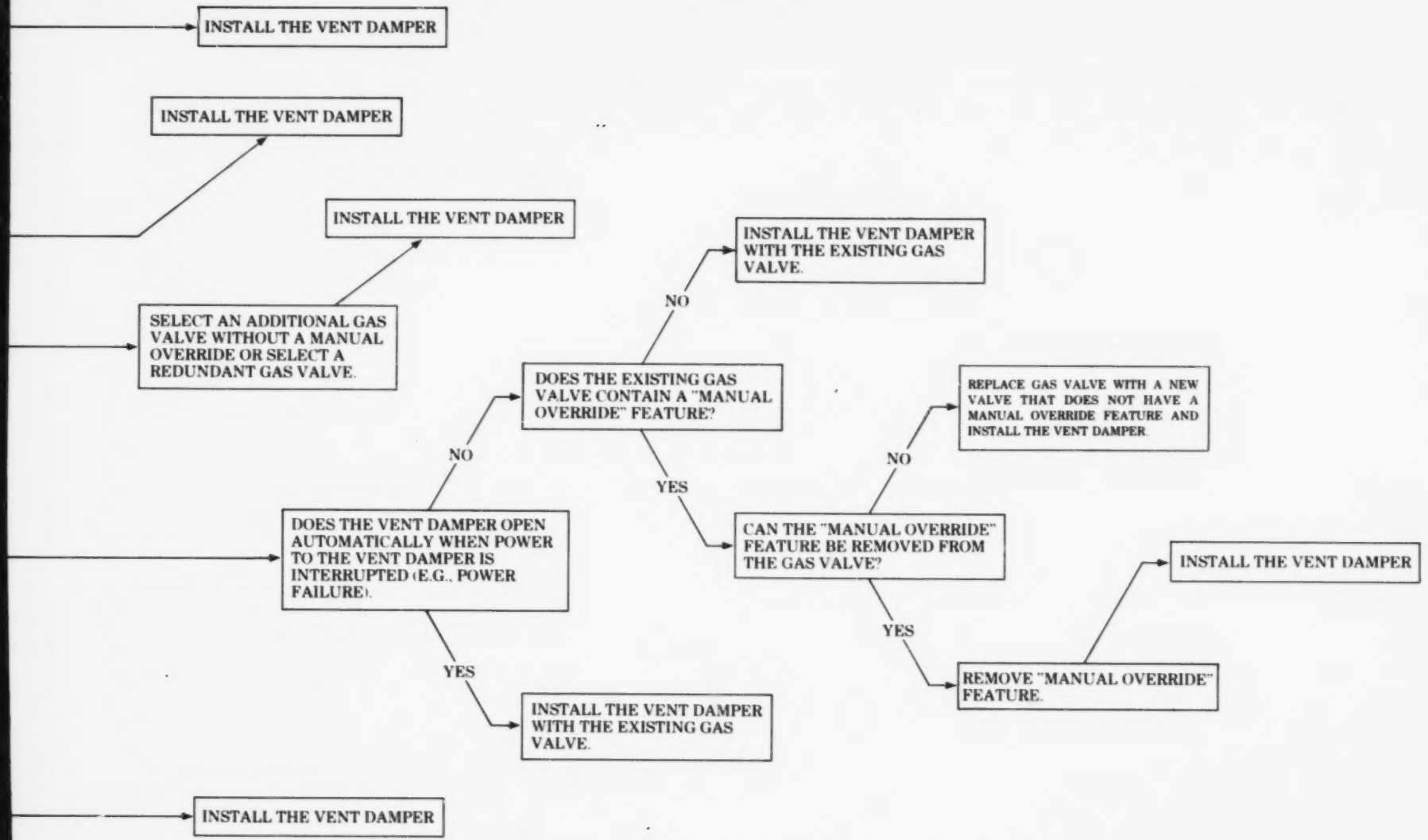
BEST DOCUMENT AVAILABLE

FIG. 7-9

ELECTRICAL VENT DAMPER SELECTION GUIDE


DO NOT PROCEED UNTIL ALL DEFICIENCIES HAVE BEEN CORRECTED.
NO
DID THE HEATING APPLIANCE PASS THE PRE-INSTALLATION INSPECTION?
YES
DO NOT INSTALL A VENT DAMPER.
NO
WAS THE TEMPERATURE AT THE CENTER OF THE FLUE PASSAGE(S) 1" BEFORE THE INLET TO THE DRAFT HOOD *GREATER* THAN 200°F BUT *LESS* THAN 550° F?
YES
SELECT A VENT DAMPER WHICH DOES *NOT* CONTAIN A DAMPER-CLOSING TEMPERATURE CONTROL.
NO
IS THE HEATING APPLIANCE EQUIPPED WITH A REDUNDANT GAS VALVE?
YES
SELECT AN ADDITIONAL GAS VALVE WITHOUT A MANUAL OVERRIDE OR SELECT A REDUNDANT GAS VALVE (SEE NOTE 2).
NO
WAS THE TEMPERATURE AT THE CENTER OF VENT CONNECTOR 6" AFTER THE OUTLET OF THE DRAFT HOOD *GREATER* THAN 375°F?
YES
SELECT A VENT DAMPER WITH AN INTEGRAL DAMPER-CLOSING TEMPERATURE CONTROL.
IS THE HEATING APPLIANCE EQUIPPED WITH A REDUNDANT GAS VALVE?
YES
NO
IS THE MINIMUM INTERNAL FREE VENTING AREA WITH THE DAMPER IN THE CLOSED POSITION AT LEAST 10% OF THE OUTLET FREE VENTING AREA?
NO
YES
NOTE 1: THIS FLOW CHART IS BASED ON PROVISIONS IN THE U.S. FEDERAL REGISTER, ANSI STANDARDS, AND ON VARIOUS MANUFACTURERS' SUGGESTIONS. BECAUSE OF VARIATIONS BETWEEN THE DIFFERENT VENT DAMPERS, YOU SHOULD ALWAYS FOLLOW THE INSTRUCTIONS THAT ACCOMPANY THE PARTICULAR VENT DAMPER YOU INSTALL.
NOTE 2: CERTAIN VENT DAMPERS CAN BE INSTALLED WITH A SPECIAL PRESSURE-OPERATED SWITCH OR GAS FLOW INDICATOR WHICH FULFILLS THE PURPOSE OF A REDUNDANT GAS VALVE. THIS TYPE OF DAMPER SYSTEM CAN ONLY BE INSTALLED IN APPLIANCES WHICH ARE NOT EQUIPPED WITH A VALVE CONTAINING A MANUAL OVERRIDE FEATURE.

BEST DOCUMENT AVAILABLE


INSTALL THE VENT DAMPER
INSTALL THE VENT DAMPER
INSTALL THE VENT DAMPER
SELECT AN ADDITIONAL GAS VALVE WITHOUT A MANUAL OVERRIDE OR SELECT A REDUNDANT GAS VALVE.
DOES THE VENT DAMPER OPEN AUTOMATICALLY WHEN POWER TO THE VENT DAMPER IS INTERRUPTED (E.G., POWER FAILURE).
NO
YES
DOES THE EXISTING GAS VALVE CONTAIN A "MANUAL OVERRIDE" FEATURE?
NO
YES
INSTALL THE VENT DAMPER WITH THE EXISTING GAS VALVE.
CAN THE "MANUAL OVERRIDE" FEATURE BE REMOVED FROM THE GAS VALVE?
NO
YES
REPLACE GAS VALVE WITH A NEW VALVE THAT DOES NOT HAVE A MANUAL OVERRIDE FEATURE AND INSTALL THE VENT DAMPER.
REMOVE "MANUAL OVERRIDE" FEATURE.
INSTALL THE VENT DAMPER
INSTALL THE VENT DAMPER
INSTALL THE VENT DAMPER WITH THE EXISTING GAS VALVE.
INSTALL THE VENT DAMPER

SELECTING VENT DAMPERS

The flow chart shown in Figure 7-8 is provided as an aid in selecting thermal vent dampers. The flow chart shown in Figure 7-9, on the other hand is an aid in selecting electrical vent dampers. Keep in mind that these charts are based on National Codes and Federal Regulations; State and Local codes may have additional requirements. As always, consult your local codes and follow the manufacturer's instructions.

INSTALLING VENT DAMPERS

There are two "general requirements" which must be taken into consideration when installing any type vent damper.

First, vent dampers *should not* be installed on appliances which are located in "unheated areas"; that is, areas or spaces which are open to the outdoors.

Second, each gas appliance must use a separate vent damper. A single vent damper *cannot* be installed in a common vent served by more than one appliance. Should only one of two appliances in the same appliance space be fitted with a vent damper, no substantial energy savings will be gained. Consideration should be given to installing a vent damper on *each* appliance within the same appliance space.

Providing that *only* a vent damper and necessary accessory components are being installed, proceed with the Installation Procedures for Vent Dampers. *However*, if an Intermittent Ignition Device is also being installed, complete the remaining material in this Section prior to attempting to install the IID.

The installation procedures for vent dampers are provided as an aid. These procedures are based on National Codes and Federal Regulations. State and Local codes may have additional requirements.

INSTALLATION PROCEDURES FOR VENT DAMPERS

STEP 1 - Complete The Pre-Inspection.

Before installing the vent damper, make sure that the pre-inspection is completed entirely and that the heating appliance is qualified for the installation of the particular vent damper. If required by local codes make sure that the responsible agency has been notified and will be available to inspect the completed installation as soon as possible. The heating appliance cannot be operated until the inspection is made.

STEP 2 - Assemble Necessary Tools and Equipment.

Prior to beginning the actual installation, make sure that you have all the tools and equipment that will be required to install the vent damper. The type of vent damper and any necessary modifications will determine the tools you will need. Those may include all or some of the following:

a. Electrical test meter (VOM).

b. Wrenches (pipe, Crescent, Allen).

c. Screwdrivers (flat-tip or Phillips).

d. Metal cutting tools (tin snips).

e. Manometer or pressure gauge.

f. Leak detecting equipment (bubble or electronic)

g. Watch.

h. Wire crimping/stripping tools.

i. Twist terminals or solderless connectors.

j. Additional electric wire.

k. Sheet metal screws and braces.

l. Tape measure.

m. Pipe nipples (for additional or new valves).

n. Thread sealing compound

STEP 3 - Prior to Beginning the Actual Installation of the Vent Damper, You Must Check for the Following:

a. Using Figure 7-8 or 7-9, check that the vent damper is compatible with the existing heating appliance and that any additional equipment, such as another gas valve, is also compatible. Check to see if there is a manual override on the gas valve and whether or not it must be removed.

b. Remove the damper from the container and check its condition. Make certain it is free from shipping damage, corrosion or visible defects and that all parts are included.

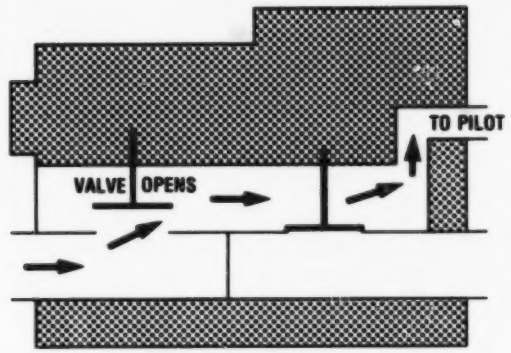
c. Check that the damper is the correct size. The damper inlet must not be smaller than the draft hood outlet.

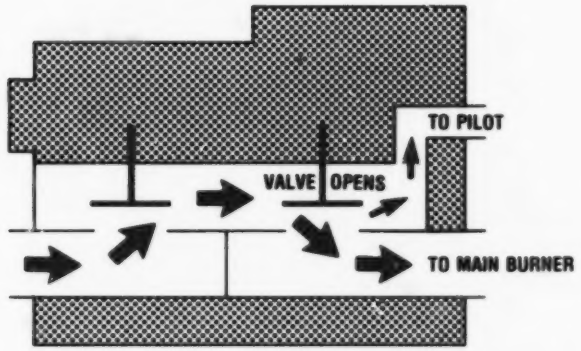
BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

FIG. 7-10

REDUNDANT VALVE





d. If the vent damper is a thermal type or electrical type with a temperature closing control, verify that the vent temperature six inches after the draft hood was above the minimum temperature requirement as described in the pre-inspection.

e. If you are installing an electrical vent damper, check the manufacturer's wiring diagrams to make sure they match the wiring of the appliance. If it does not match, contact the damper manufacturer before installing the vent damper. Check that the voltage rating of the circuit in which the damper will be installed is compatible with the damper. Also check that the transformer is of sufficient capacity for the additional load.

f. Determine that the location where the damper will be installed meets the following:

(1) No combustible materials within 6 inches of the vent damper

(2) Vent damper *is not* in a common vent and is after the draft hood.

(3) For thermal type or electrical type with damper closing control, the damper is installed within three pipe diameters of the draft hood.

STEP 4 - Shut Off the Gas and Electricity.

Shut off the gas at the valve in the supply line to the appliance and not the gas control. Turn off the electrical supply at the main power switch to the appliance. If you are installing a thermal vent damper, note the time that you turn off the gas if the appliance has been operating.

STEP 5 - Remove the Existing Vent Pipe.

If the appliance has been operating, wait until the vent pipe cools to where you can handle it safely. Loosen and remove the vent connector from the appliance draft hood or the point where the damper is going to be installed. Determine if any existing vent pipe must be modified or removed in order to install the vent damper. Some installations may not require removal of any pipe, but the system must still meet the requirements for minimum slope of the vent connector, etc.

STEP 6 - Install the Vent Damper.

Follow the manufacturer's instructions to install the vent damper onto the draft hood outlet or if applicable, onto the vent pipe. Make sure that it is installed with the arrow indicating the direction of flow away from the draft hood. Reconnect the remaining vent pipe to the other end of the damper. If it is mounted in a horizontal section, make sure that there is adequate support and that the pipe does not sag. If necessary, install sheet metal screws to secure the damper or support straps. Make sure that the screws are not located where they can interfer with the operation of the damper.

If the damper is installed in a horizontal position make certain that any control box is *not* located directly above or below the vent. The control box should be installed between the one to five *or* seven to eleven o'clock position.

STEP 7 - Install Additional Gas Valve if Necessary.

The next step is to install the additional gas valve, if required. If an additional gas valve without a pilot feature is being installed, it is placed between the existing gas valve and the main burners. If it is a gas valve with a special "gas flow detector", it is installed upstream of the existing gas valve. Make sure the gas valve is mounted in the correct flow direction.

Install the valves, using the necessary fittings and piping. Use an approved thread sealing compound and make sure the connections are gas tight.

Purge the air from the affected gas lines and conduct a gas leakage test downstream of the shutoff valve in the supply line.

STEP 8 - Make Electrical Connections.

Using the manufacturer's schematics, connect the wiring to the vent damper. Make sure that the wire is of the approved type and size. Make all connections with approved terminals or connectors. Make sure the wire is secure and routed away from locations of intense heat. If any splices are needed in the 115 VAC line voltage wiring, they must be covered by a junction box. Any line voltage wiring must be contained in a conduit.

Next, connect the wiring to the gas valve or transformer as specified by the manufacturer's instructions. Some vent dampers require connecting the damper to the hot leg of the 24 VAC transformer.

Any additional wiring must be at least No. 18 AWG wiring, thermal plas-tic, 90°C. However, if the wiring does not run inside the furnace where it is protected by the panels or in a conduit, the wire must be "Low Energy Safety Control Wire (105°C)". The wires must be secured to prevent dam-age from accidental strain. Any splices must be inside enclosures or access panels.

STEP 9 - Turn on Electrical Power to the Heating Appliance.

STEP 10 - Check the Operation and Sequence of the "Electrical" Vent Damper.

Make sure that when the gas valve is off, the damper is closed. When there is a call for heat, the damper should begin to open. Some dampers have an indicator to denote the open and closed position. The gas valve should not operate until the damper is nearly open. The gas valve should close before the damper begins to close. Dampers that are spring-loaded open should automatically open when the power is de-energized. If the vent damper is installed in a boiler, where the gas valve is sequenced by an aquastat, the damper must open before the gas valve opens.

Ensure that the damper opens and closes freely without binding or interference. In the "off" cycle, check that both the damper and gas valve are closed.

STEP 11 - Check the Thermostat Heat Anticipator.

Follow the manufacturer's instructions to determine the required setting of the thermostat heat anticipator. Usually the electrical vent dampers require the addition of .1 amps to the control circuit. Set the heat anticipator accordingly.

STEP 12 - Prepare for Spillage Test.

As far as practical, close all outside doors and windows. Turn on any exhaust fans *except a summer exhaust fan*. Turn on any clothes dryers vented to the outside. Make sure no fireplaces are operating and the fireplace dampers are closed. When installing a THERMAL vent damper, wait until it has been at least thirty minutes since the appliance cycled off before continuing to the next step.

STEP 13 - Put the Appliance in Operation.

Following the manufacturer's instructions for lighting the appliance, place it in operation and set the thermostat for continuous operation.

STEP 14 - Test for Spillage.

After the main burner of the appliance has been in operation for exactly two minutes, conduct a spillage test using a non-pressurized smoke device such as a cigarette, pipe, etc. Make sure that you can clearly determine the flow of the smoke.

If the appliance has a thermal vent damper and is equipped with a flame modulation valve, shut off the appliance after the spillage test and wait thirty minutes until it is cool. Then, turn the appliance on the lowest flame condition and perform another spillage test.

STEP 15 - Check Appliance Operation.

During operation, check the main burner to see if it is burning properly with no floating or lifting flame. If the appliance is equipped with a modulating valve, check the burners at both high and low flame conditions.

Check for proper pilot operation and main burner ignition by turning the main power switch off and on.

BEST DOCUMENT AVAILABLE

Check the pilot safety device. Ensure that the pilot safety device blocks the flow of gas to the main burner when the pilot burner has been extinguished.

If the shutoff or dropout time of the pilot safety is not known for the particular appliance, use a safety shutoff time of *one* minute.

STEP 16 - Check the Vent Operation.

For a *thermal vent damper,* cycle the heating appliance through at least *three* normal operating cycles. The damper must open and close without evidence of binding or interference. Determine that the damper closes completely *after* the thermostat and gas valve are off.

For an *electrical vent damper,* cycle the heating appliance through *three* normal operating cycles. Determine that the gas flow does not begin until the damper is nearly completely open. If the damper is *not* equipped with a temperature closing control, the damper should close when the main gas valve closes or immediately thereafter.

If the damper has a temperature closing control, operate the appliance for ten minutes; then, lower the thermostat setting to shut off the main gas valve. The damper should remain open for a period of time and then close. If the appliance is equipped with a modulating gas valve, operate the appliance at low flame for ten minutes. Then, lower the thermostat setting until the main burner is extinguished. The damper, again, should remain open for a period of time and then close.

If the damper is designed to automatically open when the power is de-energized, shut off electricity to the appliance and make sure that the vent damper opens completely.

Again, there should be no evidence of interference or binding of the vent damper.

STEP 17 - Check the Safety and Operating Controls.

For forced air furnaces, check the limit and fan controls to ensure that they have not been by-passed or readjusted and that they still operate within the manufacturer's specifications.

For hot water boilers, check the operation of the water pump and the circulating system to determine that they are operating within the limits of the manufacturer's specifications. Test the low-water cutoffs, automatic feed controls, high-pressure limit controls, high-temperature limit controls, and relief valves.

STEP 18 - Return the House to Original Condition.

Return doors, windows, exhaust fans, fireplace dampers, other appliances and thermostat(s) to their previous conditions of use.

STEP 19 - Complete Required Paperwork.

Fill out the label on the vent damper with the required information. This includes the name and address of your company, your name, and the date of the installation.

Complete the "verification of installation" card supplied by the manufacturer and return it to the manufacturer.

Leave the vent damper manufacturer's instructions in a conspicuous place near the appliance and advise the resident to read the instructions especially for observations to be performed by the resident.

STEP 20 - Notify Appropriate Authority.

As required by local codes and regulations, notify the appropriate authority that the installation has been completed. Then turn off the heating appliance until any required inspection is completed.

INTERMITTENT IGNITION DEVICES

As previously stated, intermittent ignition devices (IID's) are systems which eliminate the need for a constant pilot burner. The IID *both* cycles "on" *and* ignites the pilot only when there is a call for heat. It also cycles "off" the pilot when there is no call for heat.

Basic Structure and Operation

There are a number of different IID systems available today; however, all types consist of four basic components: a redundant gas valve, an ignition module, a spark electrode and a flame sensor.

Redundant Gas Valve

As previously discussed, the redundant gas valve uses two independent valves to control the flow of gas to the main burner. In addition, one of the two gas valves also controls the flow of gas to the pilot burner (see Figure 7-10). In this example, the two gas valves operate independently of each other. When the first gas valve opens, gas is allowed to flow through the valve and to the pilot outlet. Typically, once the pilot gas is ignited, the flame is sensed, the second gas valve opens and then allows gas to flow to the main burner.

BEST DOCUMENT AVAILABLE

Again, the use of two gas valves almost completely eliminates the possibility of gas flowing to the main burner should the gas valve malfunction in the appliance "off" cycle. Other than the addition of a "backup" valve, the redundant gas valve operates virtually the same as a conventional main gas valve.

Ignition Module

The ignition module is the "brain" of the IID system. It controls and sequences all of the IID functions. Typically, the ignition module is installed at a remote location to the redundant gas valve. However, several modules are available where the ignition module is actually attached to the redundant gas valve. Remote ignition modules are connected by a wiring harness to the gas valve and wiring of the space heating appliance.

As the brain of the IID, the ignition module must sequence or control:

1. The flow of gas to the pilot burner.

FIG. 7-11

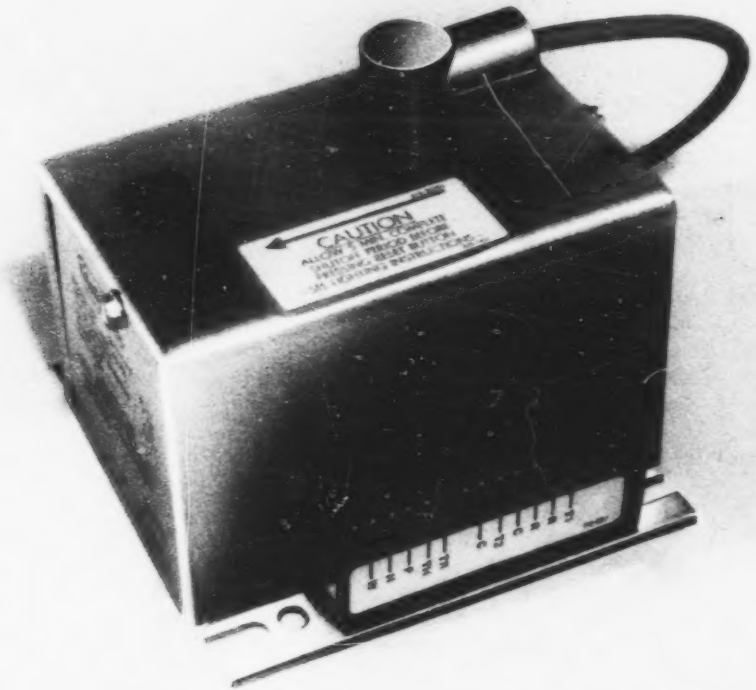
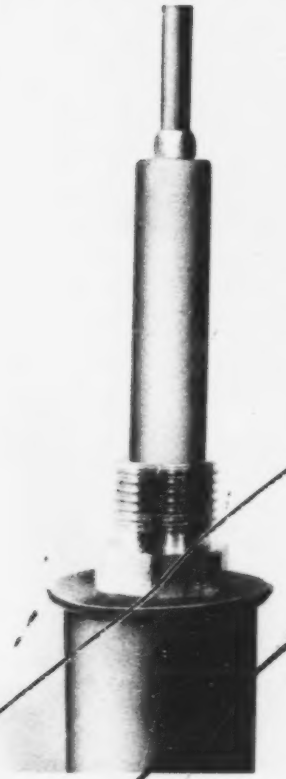


FIG. 7-12



2. The high voltage discharged at the spark electrode.
3. The proving or sensing of the pilot flame.
4. The flow of gas to the main burner.

Should the pilot flame fail to ignite, the ignition module also sequences or controls:

1. The time in which "lock-out" or IID system shutdown occurs due to an unproven pilot flame.
2. The time in which the IID attempts to reignite the pilot flame once "lock-out" has occurred.

It is important to note that some IID's automatically attempt to reignite the pilot flame once lock-out has occurred. Other IID's must manually

BEST DOCUMENT AVAILABLE

be reset should "lock-out" occur. Manually resetable ignition modules must be used on IID's which are installed on appliances operating on LP-gas (see Figure 7-11).

Spark Electrode

The spark electrode discharges high voltage from the ignition module across a specified distance or gap and creates a spark. The spark is sufficiently hot to ignite the gas supply at the pilot burner.

Typically, the spark electrode consists of an insulated metal conductor (electrode) and a high tension lead (see Figure 7-12). During the installation of some types of IID's, the electrode must be formed to the proper configuration. Then the gap between the electrodes must be adjusted within the manufacturer's specifications. In other types of IID's, the electrode is pre-formed; however, the gap must still be checked for proper adjustment.

Flame Sensor

There are two types of flame sensors that are in common use today: the hydraulic flame sensor and the electronic flame sensor (see Figure 7-13).

The *hydraulic flame sensor* consists of a bulb and capillary assembly (diastat) attached to an electrical switch. When the bulb is heated by the pilot flame, the fluid within the assembly expands through the hollow

FIG. 7-13A

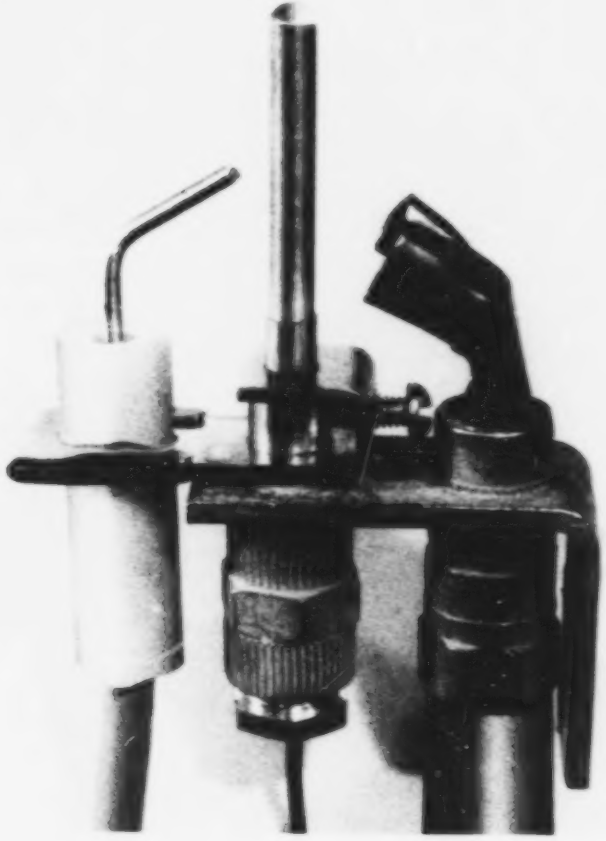
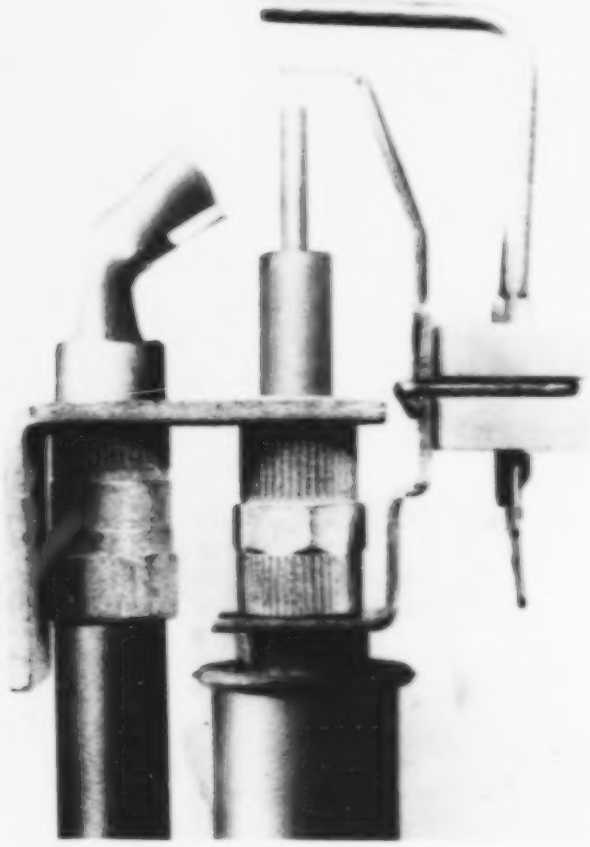


FIG. 7-13B



BEST DOCUMENT AVAILABLE

capillary and closes a switch. The closing of this switch completes a circuit to the ignition module proving the existence of the pilot flame. If the pilot is not ignited or if it goes out, the switch opens, breaking the proving circuit (see Figure 7-13A).

The *electronic flame sensor* proves the existence of a pilot flame by a principle known as "flame rectification". Simply stated, the flame itself is used to complete an electrical circuit, thereby proving the existence of a pilot flame (see Figure 7-13B).

Flame Rectification

As previously discussed, combustion is a chemical reaction. During this chemical reaction, particles called "ions" are released which can conduct electricity. This process is known as "ionization".

Some IID's use this principle to complete a circuit from the flame sensor through a pilot flame and to an electrical ground such as the pilot burner or other metal object.

Because the free ions are attracted to the conductor with the largest physical area, the circuit through the flame is directional . . . from the smaller sensor to the larger metal pilot burner. AC or alternating current is applied to the flame sensor; however, due to the directional nature of ionization, the flame rectifies or changes the AC voltage to DC. As long as the pilot is ignited the DC circuit is complete.

The fact that the flame rectifies is important because, should the sensor be damaged so that it made physical contact with the burner, the system would not operate . . . this would be an AC short. In this example, without the flame rectification to DC, the pilot flame could be proven even though it was extinguished.

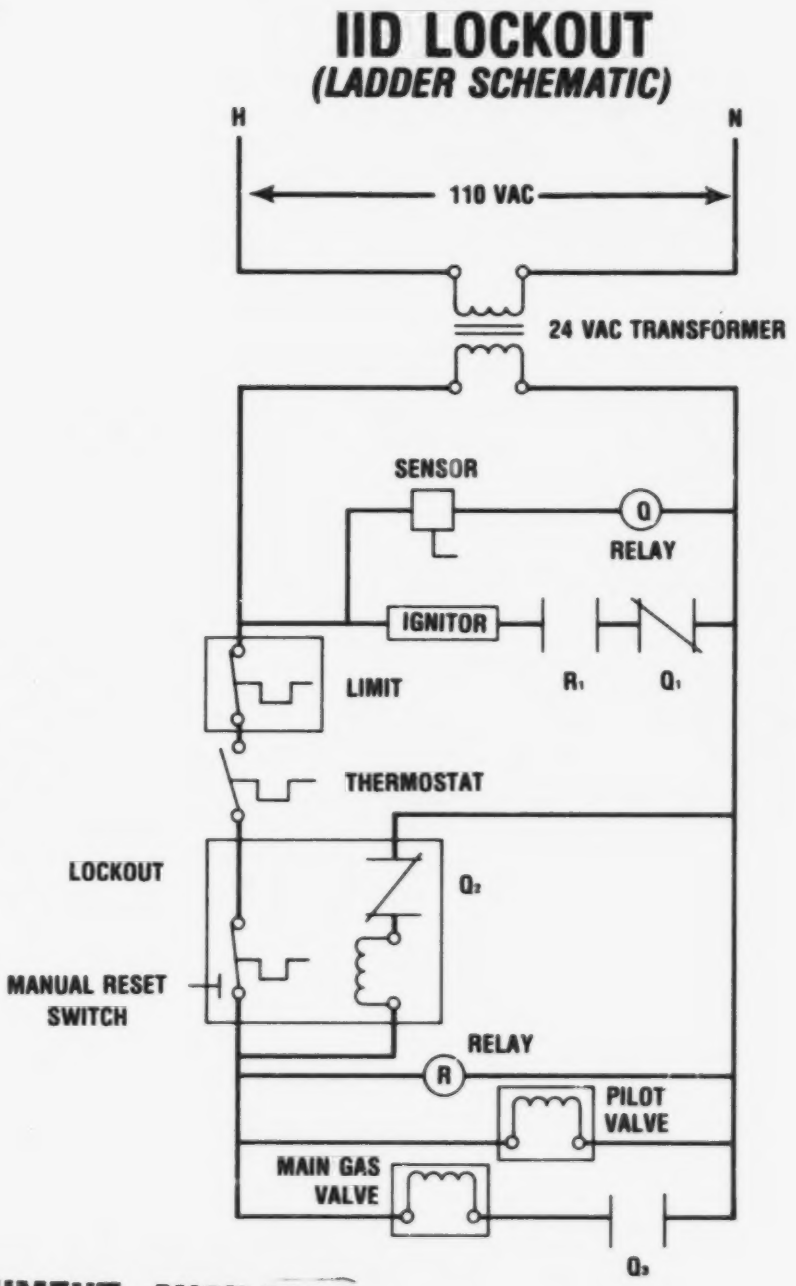
Basic Electrical Schematic

Because of the differences in IID's it is impossible to detail each specific type. For this reason, a *generic* IID schematic is shown in Figure 7-14.

When the thermostat contacts close a circuit is completed to the pilot gas valve, relay R and to a small high resistance wire inside the "lock-out" assembly. The pilot gas valve opens and allows gas to flow to the pilot burner. At the same time relay contacts R_1 close, completing the circuit to the ignitor electrode. The high resistance wire within the lock-out assembly begins to generate *heat*.

If the pilot is not proven within a specified period of time, the heat produced by the high resistance wire causes the lock-out switch to open, shutting down the entire system. It is clear to see the lock-out actually is a small time delay switch.

FIG. 7-14



BEST DOCUMENT AVAILABLE

If the pilot gas supply is ignited, it is immediately detected by the flame sensor. Once detected, the flame sensor completes a circuit to Relay Q. Relay Q opens contacts Q_1 and the ignitor electrode stops sparking. It also opens contacts Q_2 and closes Q_3, allowing the main gas valve to open so that gas can flow to the main burner where it is ignited by the pilot.

When the thermostat contacts open, relay R and relay Q deenergize, and the pilot and main gas valves close. This shuts down the system until there is another call for heat.

INSTALLING INTERMITTENT IGNITION DEVICES

Providing that *only* an IID and necessary accessory components are being installed, proceed with the installation procedure for IID's, located at the end of this section. *However*, if an IID and a vent damper are being installed, proceed with the installation procedures covering the combined installation. Notify the appropriate inspecting authority of the installation and remember that the heating appliance must be shut down until the inspection is made.

Again, the installation procedure for IID's is provided as an aid. These procedures are based on National Codes and Federal Regulations. State and Local codes may have additional requirements.

INSTALLATION PROCEDURE FOR AN IID

STEP 1 - Complete the Safety Inspection of the Heating Appliance as Required.

STEP 2 - Check For Compatibility of the IID with the Heating Appliance.

Before beginning the installation of the IID, carefully check to be sure that it is compatible with the heating appliance. Some of the items to be checked are:

a. Are the IID and heating appliance listed and approved for the intended service (fuel gas)?

b. Make certain that the gas valve capacity (BTU/HR) is sufficient for the appliance.

c. Make certain that the electrical voltage rating of the IID is the same as the appliance gas valve circuit.

d. Make certain that the transformer capacity is sufficient for the IID and any other electrical devices. (i.e. relays, etc).

e. Check the manufacturer's wiring diagrams to make sure that they match the wiring of the appliance. If they do not, contact the manufacturer for a diagram before beginning the installation.

f. Check the replacement valve to be sure that it will fit into the existing valve location.

g. Check that the control module can be located in a place that meets with the manufacturer's requirements.

h. Remove the IID components from the container. Check the condition of each part. Ensure that all the installation parts have been included and that they are free of damage.

STEP 3 - Assemble Necessary Tools and Equipment.

First, check the manufacturer's instructions and determine what additional parts will be needed for the installation.

Prior to beginning the installation of the IID, make sure that the required tools, equipment and parts are on hand.

A typical list will include:

a. Electrical test meter (VOM).

b. Wrenches; (pipe, Crescent, Allen, etc.).

c. Screwdrivers.

d. Thread sealing compound.

e. Pipe nipples of the correct length and diameter.

f. Manometer or pressure gauge.

g. Leak detecting equipment (bubble or electronic).

h. Wire crimping/stripping tools

i. Twist terminals or solderless connectors.

STEP 4 - Turn off Gas and Electricity.

Turn off the gas at the supply line to the appliance *and* not the valve on the control. Turn off the electrical supply at the main switch to the appliance.

STEP 5 - Install the IID According to the Manufacturer's Instructions.

Make sure that the procedures listed by the manufacturer are followed when installing the components of the IID. Some of the general procedures are:

a. Make sure that the pilot burner location is not changed.

BEST DOCUMENT AVAILABLE

b. Make sure the replacement gas valve is properly installed, all piping connections are tight, and that the control module is firmly mounted and protected.

c. Make sure that wiring is done in accordance with manufacturer's wiring instructions. All splices should be made either with twist terminals or solderless connectors.

d. Position the tip of the electrode so that it will arc to the location specified by the manufacturer. Set the spark gap distance according to the manufacturer's specifications.

e. Purge the air from the affected gas lines.

Some of the following steps may be included in the manufacturer's installation instructions. If they have been completed, do not repeat them.

STEP 6 - Turn on Gas and Electricity to the Appliance.

STEP 7 - Conduct a Gas Leakage Test.

Conduct a gas leakage test downstream from the shutoff valve in the gas supply line.

STEP 8 - Check the Heat Anticipator of the Thermostat.

Determine the new current draw of the thermostat circuit (with IID installed) by reading the manufacturer's literature or by adding the current draw of the IID to that of the old thermostat circuit. Set the thermostat heat anticipator accordingly.

STEP 9 - Check Wiring Connections.

Make certain that the wiring connections are tight. Be sure that all splices and wire terminals are tight and protected from intense heat. It may be necessary to reroute the electrical wiring away from problem areas.

STEP 10 - Check Burner Operation.

Set the thermostat to its highest setting. Check the manifold pressure and adjust regulator as necessary to meet the appliance manufacturer's ratings.

Be sure that the main burner is burning properly with no floating or lifting flames and no flashback on ignition.

If the appliance is equipped with a modulating gas valve, check for proper burner operation at both high *and* low flame conditions.

STEP 11 - Check Pilot Operation.

Determine that the pilot is igniting and burning properly. Check that it ignites the main burner properly. This can be done by turning the electricity on and off in a convenient manner. This should be done with the appliance burner both cold and hot. Do it as many times as necessary to determine that the IID is operating properly.

STEP 12 - Test Pilot Safety Device.

Check if the pilot safety device is operating properly. Both the main *and* pilot burners should be extinguished when there is no call for heat. If the pilot flame is not proven on a "call for heat", the main burner should remain off. For LP-gas applications, the pilot gas valve must also shut off automatically if the pilot flame is not proven. Monitor the spark igniter. Look for random or misdirected sparks. If necessary, turn off electricity and readjust spark igniter.

STEP 13 - Sequence the Appliance Through At Least Three Operating Cycles.

STEP 14 - Check the Safety and Operating Controls.

For forced air furnaces, check the limit and fan controls to ensure that they have not been by-passed or readjusted and that they still operate within the manufacturer's specifications.

For hot water boilers, check the operation of the water pump and the circulating system to determine that they are operating within the limits of the manufacturer's specifications. Test the low-water cutoffs, automatic feed controls, high-pressure limit controls, high-temperature limit controls, and relief valves.

STEP 15 - Complete Required Paperwork.

Apply the labels on the appliance as required.

Complete any manufacturer's cards as required and return to the manufacturer.

Leave the instructions in a conspicuous place and advise the resident to read the instructions, especially for inspections or observations to be performed by the resident.

BEST DOCUMENT AVAILABLE

STEP 16 - Notify Appropriate Authority.

As required by local codes and regulations, notify the appropriate authority that the installation has been completed. Turn off the heating appliance until it has been inspected.

INSTALLING COMBINATION IID AND VENT DAMPER

In some cases, you may install either a vent damper or an IID. However, in other cases, you may install both components. The installation of both components is no more difficult than the installation of the individual components; however, there are several factors you should keep in mind.

First, manufacturers which produce IID's make available a special wiring harness that is used to interconnect the gas valve and ignition module to the appliance wiring. In addition, some manufacturers of IID's also produce electric vent dampers. In these cases, the manufacturer makes available a different wiring harness to interconnect the appliance wiring to the gas valve, ignition module and electric vent damper. This obviously simplifies installation.

Manufacturers which produce both IID's and electric vent dampers may not allow the installation of their *vent damper* with another manufacturer's IID. However, they often allow the installation of their IID with vent dampers produced by other manufacturers. Due to this, manufacturers which produce only electric vent dampers *must* provide detailed instructions on wiring their vent damper with the various types of IID's. In these cases, the vent damper may not be provided with a wiring harness. If not, the instructions will direct you to run the wire by hand.

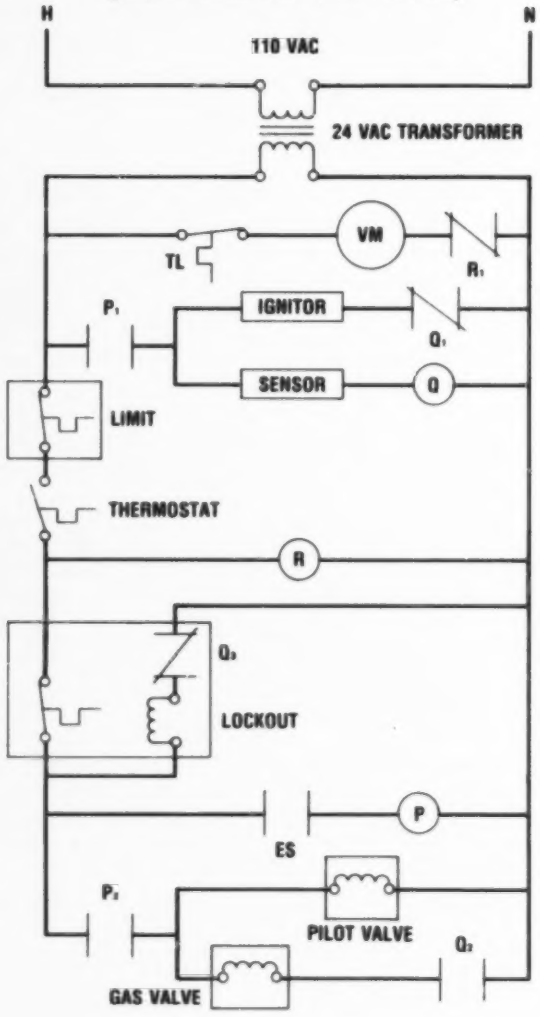
Figure 7-15 shows the basic electrical schematic for a combined IID and vent damper installation. When the thermostat contacts close, the circuit is completed to Relay R. Contacts R_1 open which deactivates the vent damper motor and allow it to open. When the baffle fully opens, end switch ES closes and energizes Relay P. Relay P activates contacts P_1 and P_2. Contacts P_1 activate the ignitor while contacts P_2 open the pilot valve. Once gas is ignited at the pilot burner, the sensor activates Relay Q. Relay Q deactivates contacts Q_1 which cycles the ignitor off. At the same time, Relay Q activates contacts Q_2 which open the main gas valve and allow gas to flow to the main burners where it is ignited by the pilot flame. Contacts Q_3 also deactivate, which proves to the IID lockout that a pilot flame is established.

As you can see, the operation of the combined installation is no more complex than the operation of the individual components.

The following installation procedures are provided as an aid. These procedures are based on National Codes and Federal Regulations. State and Local Codes may have additional requirements.

FIG. 7-15

DAMPER AND IID
(LADDER SCHEMATIC)



BEST DOCUMENT AVAILABLE

INSTALLATION PROCEDURE FOR COMBINATION IID AND VENT DAMPER

STEP 1 - Complete the Pre-Inspection.

Before installing the vent damper and IID, make sure that the pre-inspection is completed entirely. Ensure that the heating appliance is qualified for installation of the particular vent damper and that the IID is compatible with both the appliance and the vent damper. If required by local codes make sure that the responsible agency has been notified and will be available to inspect the completed installation as soon as possible. The heating appliance must be shut down until the inspection is made.

STEP 2 - Check for Compatibility. The Vent Damper and IID Should be Compatible with Each Other as well as the Heating Appliance. Check for the Following:

a. Are the vent damper, IID, and the heating appliance listed and approved for the intended service (fuel gas).

b. Using Figure 7-9 or 7-10 check to see that the vent damper is compatible with the existing heating appliance, that it will be compatible with the IID gas valve. Ensure that the damper is the correct size. The damper inlet must not be smaller than the draft hood outlet.

c. If you are installing an electrical vent damper, check the manufacturer's wiring diagrams to make sure they match the wiring of the appliance and the IID. If they do not match, contact the damper manufacturer before installing the vent damper. Check that the voltage rating of the control circuit is compatible with the damper and IID. Also check that the rating of the transformer is of sufficient capacity for the vent damper and the IID.

d. If the vent damper is a thermal type or electrical type with a temperature closing control, verify that the vent temperature six inches after draft hood was above the minimum temperature requirement as described in the pre-inspection.

e. Remove the damper and IID from the container and check each component. Is it free from any shipping damage, corrosion or any visible defects? Make sure that all the parts have been included in the container.

f. The damper location must be at least six inches from any combustible material and not in the common vent. Also, make sure that the vent damper can be installed within three pipe diameters of the draft hood outlet.

g. Make certain that the gas valve capacity (BTU/HR) is sufficient for the appliance.

h. Check the redundant valve of the IID to be sure that it will fit into the existing gas valve location.

i. Check that the IID control module can be located in a place that meets the manufacturer's requirements.

STEP 3 - Assemble Necessary Tools and Equipment.

Prior to beginning the actual installation of the vent damper and IID, make sure that the required tools, equipment, and parts are on hand.

The type of vent damper, IID and necessary modifications will determine what tools you need. Those may include all or some of the following:

a. Electrical test meter (VOM).

b. Wrenches (pipe, Crescent, Allen).

c. Screwdrivers (flat tip and Phillips).

d. Metal cutting tools (tin snips).

e. Manometer or pressure gauge.

f. Leak detecting equipment (bubble or electronic).

g. Watch.

h. Wire crimping/stripping tools.

i. Twist terminals or solderless connectors.

j. Additional electric wire.

k. Sheet metal screws and braces.

l. Tape measure.

m. Thread sealing compound.

n. Pipe nipples (for additional or new valves)

STEP 4 - Shut Off Gas and Electricity.

Shut off the gas at the valve in the supply line to the appliance and not the gas control. Turn off the electrical supply at the main switch to the appliance. If you are installing a thermal vent damper, note the time that you turn off the gas if the appliance has been operating.

STEP 5 - Remove Existing Vent Pipe.

If the appliance has been operating, wait until the vent pipe cools to where you can handle it safely. Loosen and remove the vent connector from the appliance draft hood or the point where the damper is going to be installed. Determine if any existing pipe must be modified or removed in order to install the vent damper.

BEST DOCUMENT AVAILABLE

Some installations may not require removal of any pipe, but the system must still meet the requirements for minimum slope of the connector, etc.

STEP 6 - Install the Vent Damper.

Follow the manufacturer's instructions to install the damper onto the draft hood outlet or if applicable, onto the vent pipe. Ensure that it is installed with the arrow indicating the direction of flow away from the draft hood. Reconnect the remaining vent pipe to the other end of the damper. If it is mounted in a horizontal section, make sure that there is adequate support and the pipe does not sag. If necessary, install any sheet metal screws to secure the damper or support straps. Make sure that the screws are not located where they can interfere with the operation of the damper.

If the damper is installed in a horizontal position make certain that any control box is not located directly above or below the vent. The control box should be installed between the one to five *or* seven to eleven o'clock position.

STEP 7 - Install the Intermittent Ignition Device.

Install the intermittent ignition device according to the manufacturer's instructions. Make sure that the procedure listed is followed in sequence and that each specification is met.

Some of the steps in the procedure are:

a. Make sure that the pilot burner location is not changed.

b. Make sure the replacement gas valve is properly installed, all piping connections are tight, and that the control module is firmly mounted and protected.

c. Make sure that wiring is done in accordance with manufacturer's wiring instructions. All splices should be made either with twist terminals or solderless connectors.

d. Position the tip of the electrode so that it will arc to the location specified by the manufacturer. Set the spark gap distance according to the manufacturer's specifications.

e. Purge the air from the affected gas lines.

STEP 8 - Make Electrical Connections for the Vent Damper and IID.

Now that the vent damper and IID have been installed, connect the electrical wiring using the manufacturer's instructions for a combination installation. If a wiring harness is not used, make sure that all wire for the installation is of the approved type and size. Make all connections with approved terminals or connectors. All wiring should be tightly secured and away from locations of intense heat. If any wire splices are required for 115 VAC line voltage, they must be covered by a junction box. Any line voltage must be contained in a conduit.

Next, connect the wiring to the gas valve or transformer as specified by the manufacturer's instructions. Some vent dampers require connecting the damper to the hot leg of the 24 VAC side of the transformer. Any splices for low voltage wiring must be inside enclosures with covers or access panels. Any additional wiring must be at least No. 18 AWG wiring, thermal plastic, 90°C. However, if the wiring does not run inside the furnace where it is protected by the panels or in a conduit, the wire must be "Low Energy Safety Control Wire (105°C)."

STEP 9 - Turn on the Gas.

Turn on the gas supply.

STEP 10 - Conduct a Gas Leakage Test.

Conduct a gas leakage test downstream from the shutoff valve in the gas supply line.

STEP 11 - Set the Heat Anticipator.

Follow the manufacturer's instructions to determine the required setting of the thermostat heat anticipator. Set the heat anticipator accordingly.

STEP 12 - Turn on Electricity.

Turn on the electrical power to the heating appliance at this time and set the thermostat to its highest setting.

STEP 13 - Check Operation and Sequence of "Electrical" Vent Dampers.

With the thermostat on its highest setting, the vent damper will begin to open. Some dampers have an indicator to denote the open and closed position. If the damper is installed in a boiler where the gas valve is sequenced by an aquastat, the damper must be open before the gas valve opens. Ensure that the damper opens and closes freely without binding or interference.

STEP 14 - Check the Spark Ignitor for Operation.

As soon as the vent damper is fully open, the spark ignitor will begin to spark. Once you hear the electrode sparking, observe the location of

BEST DOCUMENT AVAILABLE

the arc. Look for random or misdirected sparks. If it is not correct, turn off the power and reposition the electrode.

STEP 15 - Prepare for Spillage Test.

As far as practical, close all outside doors and windows. Turn on all exhaust fans *except for a summer exhaust fan*. Turn on any clothes dryers that are vented to the outside. Make sure no fireplaces are operating and that all fireplace dampers are closed.

When installing a "thermal vent damper" and an IID, wait until it has been at least thirty minutes since the appliance cycled off before continuing to the next step.

STEP 16 - Put the appliance in Operation.

Following the manufacturer's instructions for lighting the appliance, place it in operation and set the thermostat for continuous operation.

STEP 17 - Test for Spillage.

After the main burners of the appliance have been in operation for a perood of exactly two minutes, conduct a spillage test using a non-pressurized smoke device such as a cigarette, pipe, etc. Make sure that you can clearly determine the flow of the smoke.

If the appliance has a thermal vent damper and is equipped with a flame modulation valve, shut off the appliance after the spillage test and wait thirty minutes until it is cool. Then, turn the appliance on the lowest flame condition and perform another spillage test.

STEP 18 - Check Appliance Operation.

During appliance operation:

a. Check the manifold pressure and adjust the regulator as necessary to meet the appliance manufacturer's ratings.

b. Check the main burner to see if it is burning properly with no floating or lifting flames and that it does not flashback during ignition.

c. If the appliance is equipped with a modulation valve, check the burners at both high and low flame conditions.

d. Check the pilot for proper operation and main burner ignition by turning the main power switch off and on. This should be done with the appliance burner both cold and hot.

e. Test the pilot safety device to see if it is operating properly. Both the main and pilot burners should be extinguished when there is no call for heat. If the pilot flame is not proven on a call for heat, the main burner should remain off. For LP-gas applications, the pilot gas must also shut off automatically if the pilot flame is not proven. If the pilot flame is extinguished during the operating cycle, it must shut off the main burner gas and either act to reestablish the pilot flame or prevent the flow of gas to the main burner when the pilot ignition is energized.

STEP 19 - Sequence the Appliance Through at Least Three Operating Cycles.

For an electrical vent damper and an IID, you must determine that the ignitor does not start sparking until the vent damper is fully open. The pilot should then be ignited and the ignitor will stop sparking. Once the pilot flame is proven, the main burners will ignite. When the call for heat has been satisfied, the main burner and pilot will be extinguished and the electric vent damper will close immediately if it is not equipped with a temperature closing device. If the electric vent damper is equipped with a temperature closing device, the damper will not immediately close. If the appliance has been equipped with a modulating gas valve, operate the appliance at both low and high flame positions.

If the damper is designed to open automatically when the power is off, shut off the electricity to the appliance and make certain the vent damper opens completely.

There should be no evidence of interference or binding of the vent damper.

STEP 20 - Check the Appliance Safety and Operating Controls.

For forced air furnace, check the limit and fan controls to ensure that they have not been by-passed or readjusted and that they still operate within the manufacturer's specifications.

For hot water boilers, check the operation of the water pump and the circulating system to determine that they are operating within the limits of the manufacturer's specifications. Test the low water cut offs, automatic feed controls, high-pressure limit controls, high-temperature limit controls, and relief valves.

STEP 21 - Return the House to Original Condition.

Return doors, windows, exhaust fans, fireplace dampers, other appliances and thermostat(s) to their previous conditions of use.

BEST DOCUMENT AVAILABLE

STEP 22 - Complete Required Paperwork.

Fill out the labels for the vent damper and IID with the required information. This includes the name and address of your company, your name, and the date of the installation.

Apply the labels on the appliance or components as required.

Complete the "verification of installation" cards supplied by the manufacturer and return them to the manufacturer.

Leave the manufacturer instructions for the vent damper and the IID in a conspicuous place near the appliance and advise the resident to read the instructions especially for information on annual inspections and observations to be performed by the resident.

STEP 23 - Notify Appropriate Authority.

As required by local codes and regulations, notify the appropriate authority that the installation has been completed. Turn off the heating appliance until it has been inspected.

U.S. GOVERNMENT PRINTING OFFICE:1981—777-084 / 116

BEST DOCUMENT AVAILABLE